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APRIL 1919

SOCIETY OF AUTOMOTIVE ENGINEERS Inc.
29 WEST 39TH STREET NEW YORK

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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. IV April, 1919 No. 4

Tractor and Aeronautic Meetings

TWO highly interesting and largely attended meetings of the Society were held on Feb. 27, at Kansas City, and on March 7, at New York City, respectively. There were over 200 in attendance at the Tractor Meeting and 500 members and guests were present at New York.

Tractor Meeting

The afternoon session was devoted to consideration of four technical papers dealing with the tractor industry from the testing, fuel and design viewpoints.

The first paper, which was on Tractor Testing, by Prof. J. B. Davidson of the California State Agricultural College, outlined the different field tests which it is desirable to make on tractors intended for farm use. Particular emphasis was laid upon the drawbar horsepower and the necessity for accuracy and a clear record of the data obtained. If the actual horsepower that a tractor is capable of delivering could be determined accurately and conveniently it would not be necessary, Professor Davidson explained, to provide for such a large reserve of power, and there would also be less overloading. In this connection he pointed out that it is not practicable to eliminate the horsepower rating and instead to express the capacity of tractors by the number of plows they will pull, because of variations in the size of the plow bottoms and fluctuations in the amount of power required to pull a bottom in different soils. The importance of a standard rating to the tractor industry was brought out in the discussion of the paper, and also the fact that the National Vehicle and Implement Association has been considering the subject of tractor ratings.

The second paper, by Dr. Joseph E. Pogue of the U. S. Fuel Administration, covered practically the same ground as the paper which he presented at the Annual meeting of the Society in February. Dr. Pogue paid particular attention to the subject from the standpoint of the tractor manufacturer, and suggested the advisability of designing all types of automotive apparatus to use the same kind of fuel, which from the present outlook would of necessity be heavier than those now in use.

The third paper, on The Principles of the Wheeled Farm Tractor, by E. R. Hewitt, was the same as the one presented at the Annual Meeting of the Society, and printed in the February issue of THE JOURNAL. There was considerable contributed discussion of this paper, which is printed elsewhere in this issue of THE JOURNAL.

The last paper of the afternoon, which was presented by Prof. E. A. White of the University of Illinois, was entitled The Next Step in Agricultural Implement Design. In this paper, tribute was paid to the men who invented the principal types of agricultural machinery now in use. While for the most part they were not technically educated, they possessed genius, enterprise and courage, and most of their work which was successful was done on a cut-and-try basis. For that reason their successors continued to follow in their footsteps and work by empirical methods.

Following the afternoon meeting a dinner was held at the Hotel Baltimore, at which Finley P. Mount acted as toastmaster. Among the other speakers were Dr. Pogue, who again advocated the use of a single standardized fuel for all types of automotive apparatus, thus utilizing the entire range of petroleum products that will burn successfully in all types of internal-combustion engines. He pointed out that this would mean cheaper and easier merchandising, as well as the securing of greater fuel value per gallon of crude petroleum. In addition he favored a further splitting up of kerosene with a view to reducing the quantity of that fuel and increasing the production of gasoline.

J. B. Bartholomew, the second speaker, stated that the division between motor and horse equipment is becoming more thoroughly defined each day, and that there will be eventually only two kinds of dealers: one selling tractors, and all the farm machinery to be used with them, and the other handling only horse-drawn machinery equipment.

David Beecroft gave an illustrated talk on his trip over the devastated areas of France and Belgium. E. A. Johnston also spoke.

Aeronautic Meeting

At the meeting in New York City on March 7 it was brought out that lighter-than-air craft of very large size will soon be tried out as long-distance passenger carriers. In the first paper, entitled Commercial Future of Airplanes from an Engineer's Standpoint, by C. H. Day, it was pointed out that constitutional changes will be necessary to adapt the war-developed planes to commercial use, the most important being that which will permit landings to be made at a relatively low speed without sacrificing the desirable high flying rate. The ability of a plane to rise from or alight upon a small area will, of course, exert considerable influence upon the practical use that can be made of an airplane. Another point upon which emphasis was laid was the securing of a less delicate type of engine, Mr. Day's opinion being that the use of an air-cooled unit weighing the same for the amount of power developed as a water-cooled engine with cooling water, would be much stronger and more durable, as well as cheaper to manufacture. The use of twin engines, even for the small sizes of plane, was recommended, as it is possible for the pilot to maneuver such a plane on the ground in high winds without the

help of a gang of men to set it in the proper direction, while greater safety can be secured in flight than with a single engine. An additional argument in favor of twin engines for larger airplanes, particularly those designed for passenger traffic, was the greater comfort that could be secured for passengers.

In the second paper, by Ladislas d'Orcy, which was entitled The Case for the Airship, considerable information as to recent performance of airships was given, showing that their development in war has been little less than that of airplanes. Improvements in the mechanical structure would probably enable the lighter-than-air machines to increase greatly in size and capacity beyond present limits. Another advantage claimed for the airship was that the lifting power increases as the cube of the dimensions, while the resistance to passage through the air increases only as their square, so that by increasing the size of an airship it is possible to decrease the weight of the engines required to drive it in proportion to the total lifting power. The increase in the size of airships would also eliminate the use of light and costly metals in their construction.

The third paper of the afternoon, on Airplane Radiators, was presented by Archibald Black. This paper, which was of a very different character from the other two, contained a large amount of data dealing with the efficiency of several types of radiators, the effect of various mountings on the airplane, and other factors of importance. While the conventional mounting on the nose of the fuselage appears to be satisfactory, Mr. Black pointed out that types of radiator which are built into the wings, and thus form practically an integral part of the wing surface, give considerable promise. Methods of controlling engine temperature have been only partly developed, according to the author, who suggested that efficient automatic control could be employed, although a thermostat similar to those used on automobiles possessed certain disadvantages.

At the evening session addresses were delivered by Col. V. E. Clark, Commander J. C. Hunsaker and Brigadier-General William Mitchell. The first two dealt with the development of aircraft for the Army and Navy respectively, while General Mitchell's address dealt with the tactics of airplane combat. He told of the operations of our aircraft at the battle of St. Mihiel. The attendance at the evening session was approximately 700.

MARCH COUNCIL MEETING

At the meeting of the Council held in New York City, March 8, President Manly, Past-president Kettering, First Vice-president Bachman, Second Vice-president Keilholtz, Councilors Fergusson and Crawford, Treasurer Whittelsey and Secretary and General Manager Clarkson were present. Treasurer Whittelsey read statements of profit and loss and assets and liabilities as of the date of the meeting, and General Manager Clarkson stated that the finances of the Society were in a healthy condition and expenses well within the budget proportion for the period. The latter also reported that the attendance at the annual meeting of the Society totaled 852, and that well-attended and successful meetings were held at New York City, Feb. 10, in connection with the Motor Truck Show; at Kansas City, on Feb. 27, during the week of the Tractor Show, and at New York City on March 7, at the time of the Aeronautic Exposition. The date and place of the coming Summer Meeting was left for decision by the Council, after receipt of recommendations from the 1919 Meetings Committee.

Individual applications for membership to the number of 69, 4 applications for affiliate membership, and 6 applications for student enrollment were approved. The following transfers of membership were made:

Associate to Member Grade, Sanford Brown, F. W. Hohensee and Walter Clark Robbins.

The election of R. H. Cosgrove to Associate grade was reapproved. The resignation of Harold A. Robinson, an Associate member, was accepted.

The following changes in affiliate membership were made: The New Way Motor Co. withdrew the name of E. W. Goodnow and substituted that of C. L. Bailey.

The affiliate membership held by the Sheffield Car Co. has been changed in name to the Sheffield Plant of the Fairbanks-Morse Co., to take care of the absorption by the Fairbanks-Morse Co. of the Sheffield plant.

It was reported on behalf of the Membership Committee that 172 applications for membership had been received from Jan. 1 to March 5, 1919, inclusive, as compared with 120 for the same period in 1918. The membership of the Society included on March 8, 3768 individual members and 74 affiliate members, the latter having 91 representatives. The enrolled students numbered 413 on this date.

Standards Committee

Chairman Bachman of the Standards Committee submitted a report outlining the personnel for 1919 for several divisions, which was approved. The list is given below.

BALL AND ROLLER BEARINGS DIVISION

F. G. Hughes, *Chairman*

W. C. Baker	F. C. Goldsmith
W. L. Batt	F. W. Gurney
George R. Bott	H. J. Porter
E. R. Carter, Jr.	R. G. Schaffner
D. F. Chambers	W. R. Strickland
F. M. Germane	R. E. Wells

ELECTRICAL EQUIPMENT DIVISION

W. A. Chryst, *Chairman*

F. W. Andrew	T. L. Lee
Joseph Bijur	B. M. Leece
R. J. Broege	A. D. T. Libby
W. A. Frederick	H. E. Rice
C. F. Gilchrist	A. H. Timmerman

ENGINE DIVISION

C. C. Hinkley, *Chairman*

R. J. Broege	A. F. Milbrath
W. A. Frederick	H. C. Snow
E. G. Gunn	

IRON AND STEEL DIVISION

F. P. Gilligan, *Chairman*

R. R. Abbott
F. E. Cardullo
H. L. Greene
W. B. Hurley (conferee)
F. E. McCleary
G. L. Norris
J. H. Parker
E. A. Riotte
C. F. W. Rys
H. J. Stagg, Jr.
K. W. Zimmerschied

LIGHTING DIVISION

M. W. Hanks, *Chairman*

Paul F. Bauder
William T. Jones
W. A. McKay
C. A. Michel
C. F. Kettering
Edward S. Preston
C. H. Sharp (conferee)

MISCELLANEOUS DIVISION

E. H. Ehrman, *Chairman*

Clarence Carson
C. S. Crawford
W. C. Keys
W. H. Knowles
E. E. Sweet
Fred Whittington

SHAFT FITTINGS DIVISION

C. W. Spicer, *Chairman*

J. F. Barr
W. H. Diefendorf
R. R. Lapointe
W. C. Lipe
William MacGlashan

SPRINGS DIVISION

W. M. Newkirk, *Chairman*

Ralph H. Brown
E. A. DeWaters
S. P. Hess
Harry R. McMahon
R. A. Schaaf

STATIONARY ENGINE AND LIGHTING PLANT DIVISION

L. S. Keilholtz, *Chairman*

H. N. Edens
Theodore Menges
A. H. Timmerman
George E. Tubbs

TRACTOR STANDARDS DIVISION

Dent Parrett, *Chairman*

J. B. Bartholomew
H. C. Buffington
L. W. Chase
C. M. Eason
T. B. Funk
E. R. Greer
R. O. Hendrickson
H. L. Horning
E. A. Johnston
Amos F. Moyer
J. F. Max Patitz
Wayne H. Worthington
G. A. Young

TRANSMISSION DIVISION

A. W. Copland, *Chairman*

A. T. Brown
A. C. Bryan
A. A. Gloetzner
L. C. Fuller
E. W. Miller
E. E. Wemp

TRUCK STANDARDS DIVISION

L. P. Kalb, *Chairman*

Ralph W. Austin
A. K. Brumbaugh
John R. Coleman
Frank W. Davis
Col. B. F. Miller
W. T. Norton, Jr.
A. J. Scaife
George W. Smith
E. E. Wemp
F. A. Whitten

ADMINISTRATIVE COMMITTEES

The following appointments to 1919 Administrative Committee were announced by President Manly:

CONSTITUTION COMMITTEE

Edward Orton, Jr.

FINANCE COMMITTEE

H. M. Swetland, *Chairman*

Hugh Chalmers
Christian Girl
George H. Houston
Henry R. Sutphen

HOUSE COMMITTEE

C. F. Kettering, *Chairman*

B. J. Arnold
H. E. Coffin
James Hartness
H. G. Stoddard

MEETINGS COMMITTEE

David Beecroft, *Chairman*

B. S. Koether
Dent Parrett
C. F. Scott

MEMBERSHIP COMMITTEE

C. C. Hinkley, *Chairman*

J. T. R. Bell
F. A. Cornell
Lon R. Smith
J. G. Utz

PUBLICATION COMMITTEE

Daniel Roesch, *Chairman*

Alexander Klemin
Herbert C. Sadler
H. C. Snow
G. A. Young

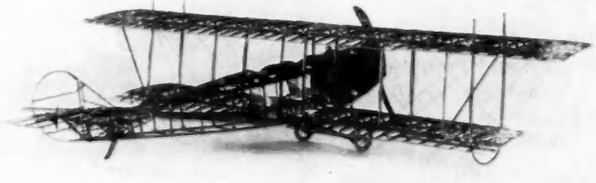
SECTIONS COMMITTEE

C. S. Crawford, *Chairman*

Joseph A. Anglada
W. A. Brush
H. R. Corse

Past-president Kettering was appointed a representative of the Society on the engineering division of the National Research Council.

The next meeting of the Council will be held in New York City on April 12.



Progressive and Retrogressive Designing

By Otto M. Burkhardt[1] (*Member*)

Buffalo Section Paper *Illustrated with* Diagrams

IF a designer is endowed with a limited amount of originality he may consider himself well adapted to his chosen occupation. Originality somewhat resembles fire and water; it can be dangerous if carelessly employed. Equally dangerous is the mania for imitating. In this age of commercialism we know that many imitations of perfectly good originals have proved to be dismal failures.

I propose to discuss some practical examples representative of correct as well as wrong methods in designing. As there is perhaps nothing at present of greater interest to all of us than our means of transportation, let us study a motor vehicle.

The mechanism of a motor vehicle should, for many very obvious reasons, be a model of simplicity. In consequence the elimination of certain links and members here and there has become more or less desirable. However, if one member is to be discarded, it is essential to know how much more other members will be burdened. Frequently strengthening or even redesigning becomes necessary.

Torque and Radius Rods

Let us take as a specific example the elimination of the torque and radius rods. The reaction of the torque transmitted to the driving wheels of a motor vehicle has a tendency to lift the front wheels off the ground. In fact, if the torque were sufficient and the resistance to rolling large enough, as would be the case with fixed wheels, the chassis would turn about the driving wheels. The torque necessary to raise front wheels off the ground, as illustrated in Fig. 1, is:

$$T \times R = W_f \times b$$

In this equation

T = Tractive force at circumference of driving wheels in pounds
R = Radius of driving wheels in inches
W_f = Load on front wheels in pounds
b = Length of wheelbase in inches

From this equation we find that the force tending to lift the front wheels off the ground, if a certain torque $T \times R$ is transmitted through the rear wheels, can be expressed by the equation $W_f = \frac{T \times R}{b}$

Let us denote by W the weight of a motor truck when loaded. The weights on the rear and front wheels will be about

$$W_r = \frac{3\ W}{4} \text{ and } W_f = \frac{W}{4} \text{ respectively}$$

The tractive force of heavy commercial vehicles is generally smaller than $0.6W_r$, but for passenger cars it is frequently larger. We may, therefore, take it as a practical average value. For a wheelbase of 8.4 times the radius of the driving wheels, we find that under the given circumstances the force tending to lift the front wheels off the ground is

$$W_f = \frac{T \times R}{b} = \frac{0.6 \times W_r}{8.4} = 0.0536\ W$$

The latter amount is equal to 21½ per cent of the weight on the front wheels. As this phenomenon lends itself admirably to the determination of the tractive force, it was utilized in some well-known experiments by Professor Riedler.

We may now with advantage apply our equations to a practical example. This shall be a 5-ton truck of 20,000 lb. gross weight exclusive of unsprung weight. Hence

$$W = 20{,}000 \text{ lb.}$$

$$W_r = \frac{3\ W}{4} = 15{,}000 \text{ lb.}$$

$$W_f = \frac{W}{4} = 5000 \text{ lb.}$$

The truck is equipped with an engine developing 50 hp. at 1000 r.p.m. The total gear reduction is 50 to 1

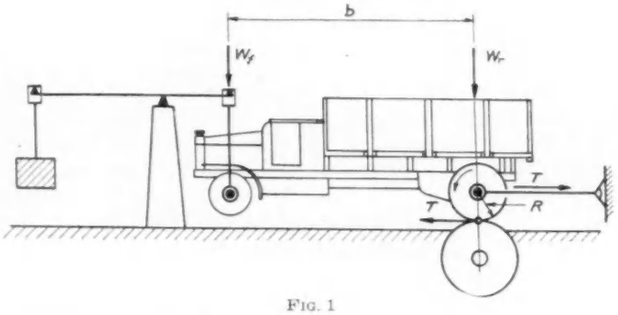


Fig. 1

in low gear and the efficiency of the mechanism we shall take as 80 per cent. The efficiency is usually taken as 70 per cent if the maximum drawbar pull is to be determined. The latter figure includes the rolling losses, whereas in our case only the losses between engine and rear axle can be subtracted.

We obtain therefore a driving-power reaction moment of

$$T \times R = \frac{50 \times 63{,}024}{1000} \times 50 \times 0.8 = 126{,}000 \text{ in-lb.}$$

With a 14-ft. or 168-in. wheelbase, Fig. 2, we obtain a force tending to raise the front axle of

$$W'_f = \frac{126{,}000}{168} = 750 \text{ lb.}$$

The chassis shown in Fig. 2 is provided with a torque rod. This member, as is well known, is employed to impart the wheel-power reaction to the frame. As the

[1]Mathematicl research engineer, Pierce-Arrow Motor Car Co., Buffalo, N. Y.

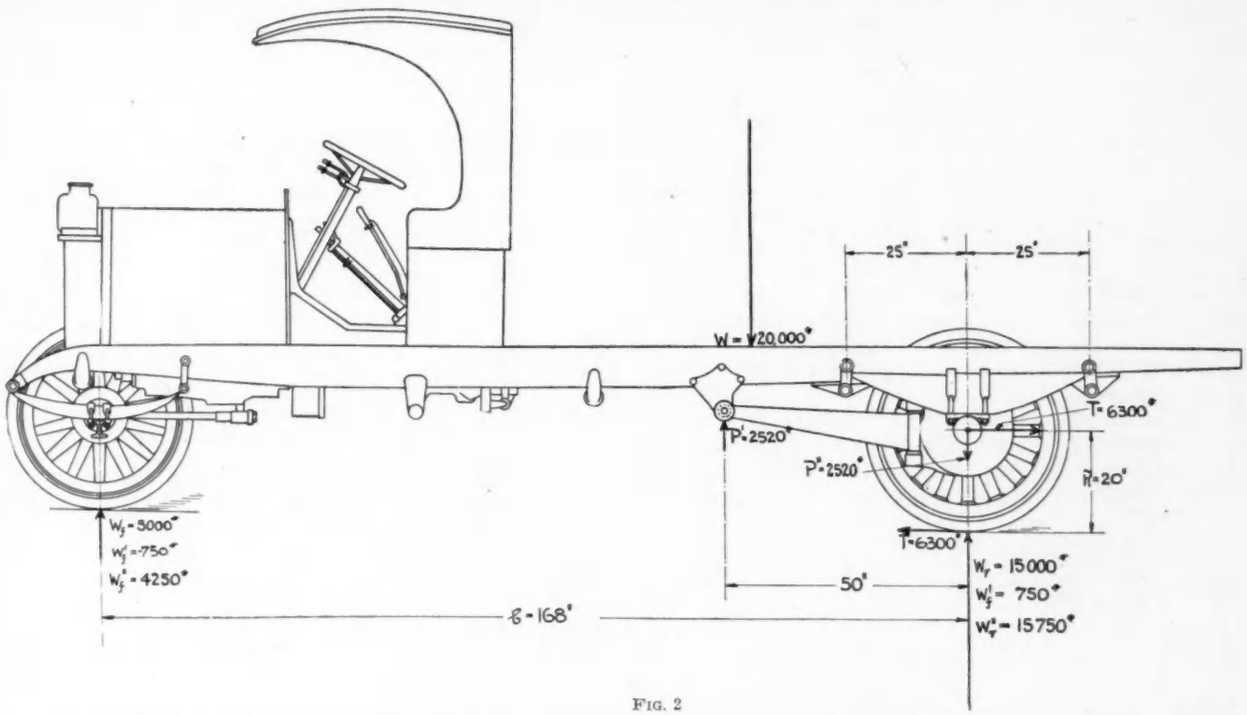


FIG. 2

torque rod is 50 in. long, it is evident that the pressure exerted at the front end of it is

$$P' = \frac{126{,}000}{50} = 2520 \text{ lb.}$$

This pressure is comparatively small and easily taken care of.

As a single force cannot balance a couple, we must have another force equal and opposite to P' with its point of application in the center of the axle. The latter force, being the reaction of the former, has been denoted by P''. We shall now resolve the force P' into two components P'_f and P'_r with their points of application in the centers of the front and rear axles respectively. The former of the two components is what we have thus far known as W'_f, as we shall presently see. It is

$$P'_f = \frac{P' \times 50}{168} = \frac{2520 \times 50}{168} = 750 \text{ lb.} = W'_f$$

$$P'_r = \frac{P' \times 118}{168} = \frac{2520 \times 118}{168} = 1770 \text{ lb.}$$

If we now subtract P'_r from P'' we obtain

$$P'' - P'_r = 2520 - 1770 = 750 \text{ lb.}$$

The force $P'' - P'_r$ is therefore also equal to W'_f, but acting in the opposite direction.

From this it follows that when maximum torque is transmitted through the rear wheels, the respective loads on the rear and front wheels have changed to

$$W''_r = W_r + W'_f = 15{,}750 \text{ lb. and}$$
$$W''_f = W_f - W'_f = 4250 \text{ lb.}$$

Let us now take another torque rod the same length as the one just considered but anchored to the rear axle in such a way that both ends can be fastened to the frame at equal distances from the center of the rear axle. It is evident that in this case the pressures on both ends of the torque rod will be the same, i.e., 2520 lb. If, however, we choose a rear spring to take the place of the torque rod the whole condition is changed.

To prove our contention a chassis has been shown in Fig. 3, in which the springs take the place of the torque rod. With the same power and gear ratio we have the same driving power reaction moment as before, *i.e.* 126,000 in-lb. The force couple constituting this driving power reaction moment we have denoted by P' and P''. It is in this case

$$P' = P'' = \frac{126{,}000}{25} = 5040 \text{ lb.}$$

Resolving P' into P'_f and P'_r gives

$$P'_f = \frac{5040 \times 25}{168} = 750 \text{ lb.}$$

$$P'_r = \frac{5040 \times 143}{168} = 4290 \text{ lb.}$$

Since $P'_f = W'_f$ we have as in the former case

$$W''_f = W_f - P'_f = 5000 - 750 = 4250 \text{ lb. and}$$
$$W''_r = W_r + P'' - P'_r = 15{,}750 \text{ lb.}$$

The force P'' must be considered as an addition to the weight of the rear axle. Now it must be conceded that it is essential to reduce all unsprung weight to a minimum. The spring supported weight acting on the front wheels of either chassis is as previously pointed out

$$W_f - P'_f = 5000 - 750 = 4250 \text{ lb.}$$

Hence the load per spring bolt is

$$\frac{4250}{4} = 1062.5 \text{ lb.}$$

Similarly the spring supported weight acting on the rear wheels of the chassis with the torque rod shown in Fig. 2 is

$$W_r - P'_r = 15{,}000 - 1770 = 13{,}230 \text{ lb.}$$

and the load per spring bolt is

$$\frac{13{,}230}{4} = 3307.5 \text{ lb.}$$

The spring supported weight acting on the rear wheels of the chassis without torque rod, Fig. 3, is

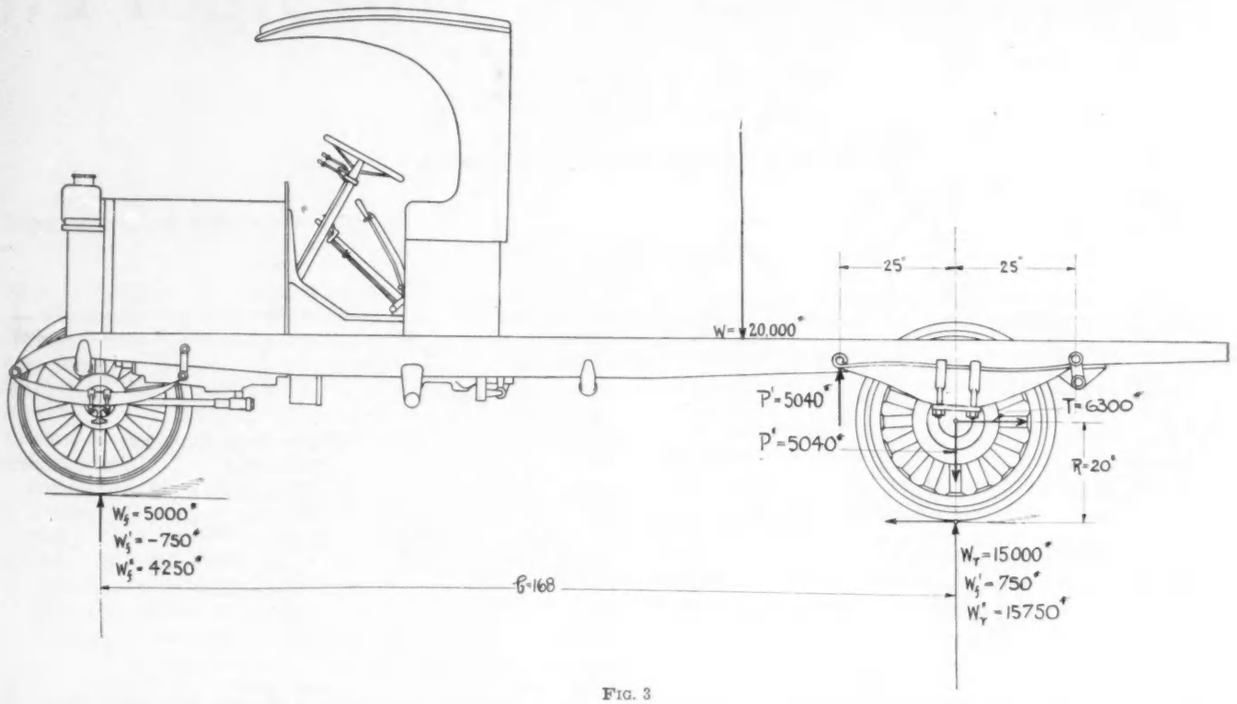


FIG. 3

$$W_r - P'_r = 15{,}000 - 4290 = 10{,}710 \text{ lb.}$$

The load on two of the rear spring bolts is consequently

$$\frac{10{,}710}{2 \times 2} = 2677.5 \text{ lb.}$$

while the other two each carry a load of

$$2677.5 + 2520 = 5197.5 \text{ lb.}$$

INFLUENCE OF BRAKES

Before we can draw any definite conclusions with regard to the maximum load on the springs we have to consider what happens when the brakes are applied. If the brakes are in good condition and applied with some force, it should be possible to lock the wheels. This elicits a braking power moment of about

$$15{,}000 \times 0.6 \times 20 = 180{,}000 \text{ in-lb.}$$

This braking power acts in a direction opposite to the driving power and consequently the directions of the forces constituting the reaction are reversed, or, in case of the Hotchkiss drive, Fig. 3, the rear halves instead of the front halves of the rear springs impart the reaction to the chassis. We observe that the braking power is 43 per cent larger than the driving power. In determining this figure no account has been taken of the amount of load of which the rear wheels are relieved if the brakes are applied, because the braking power may be even larger, as stated, if chains are used.

Now in the chassis shown in Fig. 2 we have when the brakes are applied an addition to the spring supported load of

$$P' = P'' = \frac{180{,}000}{50} = 3600 \text{ lb.}$$

This is distributed over the front and rear axle in inverse proportion to the distances, hence

$$P'_f = P' \times \frac{50}{168} = 1070 \text{ lb. and}$$

$$P'_r = P' \times \frac{118}{168} = 2530 \text{ lb.}$$

The loads on the front and rear wheels are

$$W''_f = W_f + P'_f = 5000 + 1070 = 6070 \text{ lb. and}$$
$$W''_r = W_r - P'' + P'_r = 15{,}000 - 3600 + 2530 = 13{,}930 \text{ lb.}$$

The maximum spring supported weight acting on the front wheels is 6070 lb. Hence the load per front spring bolt is

$$\frac{6070}{4} = 1517.5 \text{ lb.}$$

The maximum spring supported weight acting on the rear wheels is

$$W_r + P'_r = 15{,}000 + 2530 = 17{,}530 \text{ lb.}$$

The maximum load per rear spring bolt therefore is:

$$\frac{17{,}530}{4} = 4382.5 \text{ lb.}$$

as against a nominal load, for which the springs are generally designed, of

$$\frac{15{,}000}{4} = 3750 \text{ lb.}$$

From this it follows that, if a torque member is provided, the springs are subjected to an overload of less than 17 per cent under the worst condition.

In the chassis without the torque rod, Fig. 3, we have when the brakes are applied

$$P' = P'' = \frac{180{,}000}{25} = 7200 \text{ lb.}$$

The load P' is acting on the two rear bolts of the rear springs. It is balanced by the two loads P'_f and P'_r. It is

$$P'_r = P' \times \frac{168 + 25}{168} = 8270 \text{ lb.}$$

In this case it must be noted that P'_f is negative, acting in the opposite direction to P'. This is evident from

the point of application of P'. Since $P' = P'_r + P'_f$ it follows

$$P'_f = 7200 - 8270 = -1070 \text{ lb.}$$

The loads on front and rear wheels are now

$$W''_f = W_f - P'_f = 5000 + 1070 = 6070 \text{ lb.}$$
$$W''_r = W_r - P'_r + P'' = 15{,}000 - 8270 + 7200 = 13{,}930 \text{ lb.}$$

From this it follows that the maximum spring supported weight on the front wheels is 6070 lb.; hence the load per spring bolt is

$$\frac{6070}{4} = 1517.5 \text{ lb.}$$

Furthermore, the front bolts of the rear springs carry a load of

$$\frac{15{,}000 - 8270}{4} = 1682.5 \text{ lb.}$$

The rear bolts of the rear springs are loaded with

$$1682.5 + \frac{7200}{2} = 5282.5 \text{ lb.}$$

The different results so far obtained are given in the accompanying table.

	Load on front wheels, lb.	Load on rear wheels, lb.	Load per front spring bolt, lb.		Load per rear spring bolt, lb. In front of axle		Back of axle	
			Nominal	Actual	Nominal	Actual	Nominal	Actual
Driving in Low Gear								
Chassis with Torque Rod	4,250	15,750	1,250	1,062.5	3,750	3,307.5	3,750	3,307.5
Chassis without Torque Rod	4,250	15,750	1,250	1,062.5	3,750	2,677.5	3,750	5,197.5
Brakes Applied								
Chassis with Torque Rod	6,070	13,930	1,250	1,517.5	3,750	4,382.5	3,750	4,382.5
Chassis without Torque Rod	6,070	13,930	1,250	1,517.5	3,750	1,682.5	3,750	5,282.5

From the table we observe that the rear springs for all forward speeds have to carry less load than when the vehicle is standing still. The difference is 12 per cent for low-gear driving. In the vehicle without a torque member the rear springs under all running conditions

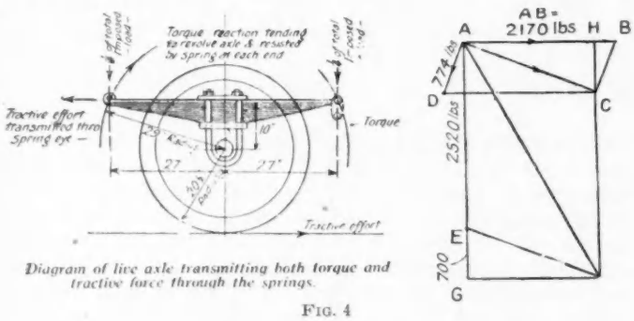


Diagram of live axle transmitting both torque and tractive force through the springs.

FIG. 4

have to carry more than the nominal load when vehicle is standing still. The increase in load is about 40 per cent for low-gear driving as well as when the brakes are applied. From this it follows that much stiffer springs must be fitted to a vehicle if the torque rod is to be eliminated. Of two vehicles designed according to a certain standard of engineering, the one with the torque rod necessarily must be by far the better for riding.

Fig. 3 illustrates how unequally the springs deflect. This accounts for the well-known phenomenon that in most of the Hotchkiss-drive arrangements as we know them today the brakes hold all right if applied gently, but not if applied vigorously. The trouble with loose spring clips, closely associated with the Hotchkiss-drive arrangement, is also so well known that it needs no further mention. Furthermore, it is well known that the speed of the vehicle is dependent upon the suspension. A vehicle equipped with a torque rod may, therefore, safely be operated at somewhat higher speed than one without this member.

Thus far we have assumed that the reaction of the tractive force is a constant drawbar pull acting in the center of the rear axle. In practice the tractive force is generally utilized to accelerate the gross weight of the vehicle, and to overcome road resistance or resistance due to gradients. During acceleration the reaction of the tractive force has its point of application in the center of gravity of the vehicle. When gradients are negotiated at a constant rate of speed or under other constant running conditions, the reaction has its point of application in the front end of the radius rods, if such are provided, or in the front spring-bolts in the Hotchkiss-drive arrangement.

Now every engineer knows that the center of gravity of a motor vehicle, as well as the other points of reaction already mentioned, are generally farther from the ground than the center of the rear axle. Consequently we have in these cases to deal with a driving-force reaction moment of much greater magnitude than those thus far considered.

Such fundamental principles are being neglected. This we see from Figs. 4 and 5, which are reproduced from articles in one of the leading trade papers. In Fig. 4 we note that the writer states, "Torque reaction resisted by spring at each end." This we have proved to be an erroneous conception. Furthermore, we learn from the magnitude of the forces that the writer imagines the reaction of the tractive force to be acting in the center of

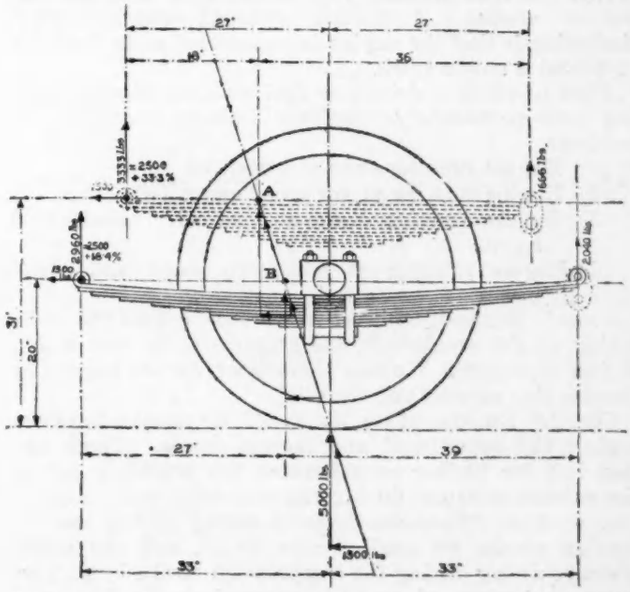


FIG. 5

the axle, whereas in reality it is acting through the top leaf of the spring. The writer shows it there but neglects it, thus making it appear to be good designing to place the spring far above the axle.

It is quite natural that almost nobody, least of all an advocate of the underslung-spring design, can reconcile himself to such a conclusion. This, however, is no reason why another hypothesis should be invented, since in an exact science like mathematics or mechanics there is no need for hypotheses. Nevertheless, we find in another article by a well-known company the opinion that a load acting vertically in the center of a perfectly symmetrical

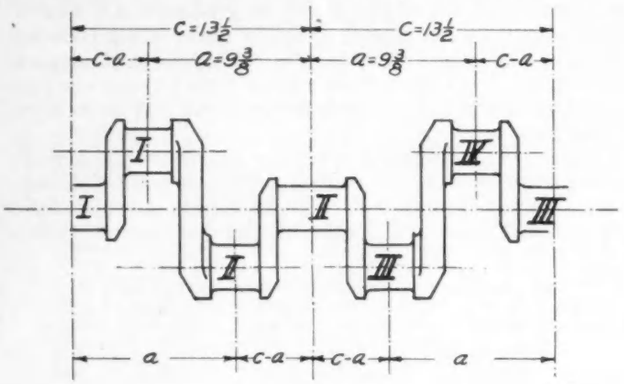


FIG. 6

spring can impose unequal loads on the spring-bolts. Fig. 5 is a reproduction from this article and shows the fallacy.

CRANKSHAFT BEARING SIZES AND LOADS

I have found a good deal of misconception among designers in regard to crankshaft-bearing proportions. This impelled me to derive a scientific basis of design from the axiom that the capacity of a bearing is primarily a function of the load it has to carry, rubbing velocity and temperature being the same in all cases. This axiom, however, requires a separate analysis for each category of engines. I shall therefore limit the present investigation to the most popular of all engines today, the four-cylinder, four-stroke cycle internal-combustion engine. A further although less important limitation is that the engine is understood to be designed to propel a motor truck.

First of all, it is necessary that we ascertain the bearing loads pertaining to the four limiting modes of propulsion:

(1) Engine running light at low speed,
(2) Engine running at low speed under full power,
(3) Engine running light at maximum speed, 1000 r.p.m.,
(4) Engine running at maximum speed under full power.

Case I We find, with regard to Case I, that the loads acting on the crankshaft will necessarily be very small, in fact negligible. We may therefore from the beginning dismiss this case as uninfluential.

Case II Because of the low speed, we may in this case neglect the centrifugal and inertia forces. There are then left for further consideration the pressures due to the gaseous mixture, during the expansion and compression strokes. The mean pressure acting during the expansion stroke we shall denote by P, and the mean pressure acting during the compression stroke by p. The average pressure, p', on any one crankpin for four consecutive strokes, i.e., expansion, exhaust, suction and compression, is then

$$p' = \frac{P + O + O + p}{4} = \frac{P + p}{4}$$

From the diagram in Fig. 10, which is designed for one particular engine, to be specified further on, we obtain $P = 2380$ and $p = 272.5$. Hence for this specific case we obtain an average crankpin pressure of

$$p' = \frac{2380 + 272.5}{4} = 663 \text{ lb.}$$

The crankpin load is imparted to the main bearings in definite proportions. Referring to Fig. 6, we note that these partial loads on main bearing I may be expressed as follows:

Expansion in cylinder I $= P \times \frac{a}{c}$ lb.

Exhaust in cylinder I $= 0$ lb.
Suction in cylinder I $= 0$ lb.

Compression in cylinder I $= p \times \frac{a}{c}$ lb.

Expansion in cylinder II $= P \times \frac{c-a}{c}$ lb.

Exhaust in cylinder II $= 0$ lb.
Suction in cylinder II $= 0$ lb.

Compression in cylinder II $= p \times \frac{c-a}{c}$ lb.

From this we derive that the average pressure on the main bearing I during one complete cycle is expressed by

$$p' = \frac{P\,\frac{a}{c} + p\frac{a}{c} + P\frac{c-a}{c} + p\frac{c-a}{c}}{4} = \frac{P + p}{4}$$

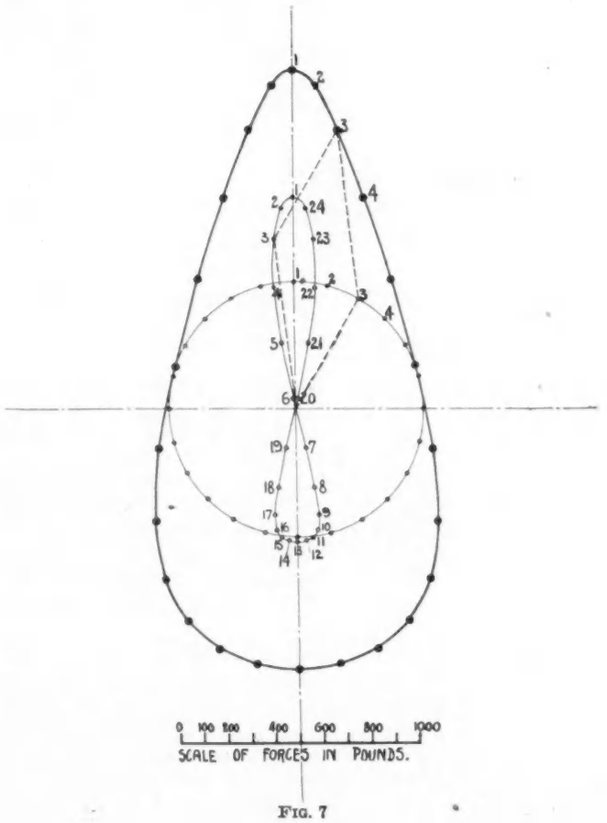


FIG. 7

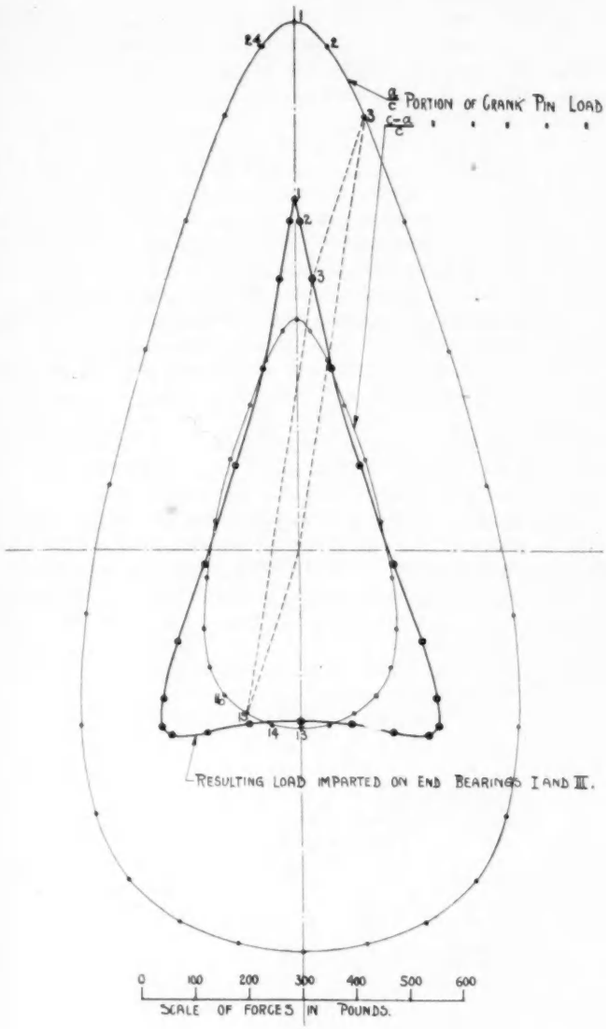

Portion of Crank Pin Load
Resulting Load imparted on End Bearings I and III.
0 100 200 300 400 500 600
Scale of Forces in Pounds.

Fig. 8

Identically the same loads as enumerated above are imparted on main bearing III in consequence of the forces acting in cylinders III and IV. All forces here under consideration are acting in the same direction. It is therefore evident that the average load on the center bearing must be the difference between the sum of all the average loads acting on the four crankpins less those resisted by the two end bearings; hence, the average pressure on the center bearing during four strokes is

$$p'' = 4 \times \frac{P+p}{4} - 2 \times \frac{P+p}{4} = \frac{P+p}{2}$$

For our particular example we obtain for the end bearings I and III an average pressure of

$$p' = \frac{2380+272}{4} = 663 \text{ lb.}$$

and for the center bearing we obtain

$$p'' = \frac{2380+272}{2} = 1326 \text{ lb.}$$

Case III We may neglect the pressures due to the gaseous mixture in this case. The only forces to be considered are those due to the inertia of the reciprocating parts and the centrifugal forces. Now as the inertia forces are affected by the angularity of the connecting-rod, and as the centrifugal force is continually changing its direction, no simple universal formula can be evolved from which to determine the magnitude and direction of the various mean pressures, as in the former case. I shall therefore confine myself to one particular example.

In a four-cylinder engine of 4½-in. bore and 6¾-in. stroke the total reciprocating weight consisting of piston with pin, rings, set-screw and the small end of the connecting-rod is 7½ lb. The total rotating weight acting on one crankpin is 5½ lb. The inertia and centrifugal forces are all calculated for 1000 r.p.m. of the engine.

The graphical representation of magnitude and direction of the inertia forces acting on the crankpin during one revolution resembles a lemniscate, as shown in Fig. 7. This diagram of forces includes certain horizontal component forces which have their origin in the angularity of the connecting-rod. The concentric circle shown in the same figure represents the centrifugal forces, 530 lb., acting on the crankpin. If now the inertia forces are combined with the centrifugal forces, as indicated by the dotted lines for one crank position, we obtain a diagram of elliptical shape which represents the magnitude and direction of the resulting loads on the crankpin.

From the last named diagram we find that the maximum load on the crankpin is 1415 lb., the minimum load 530 lb. and the average load 940 lb. These crankpin

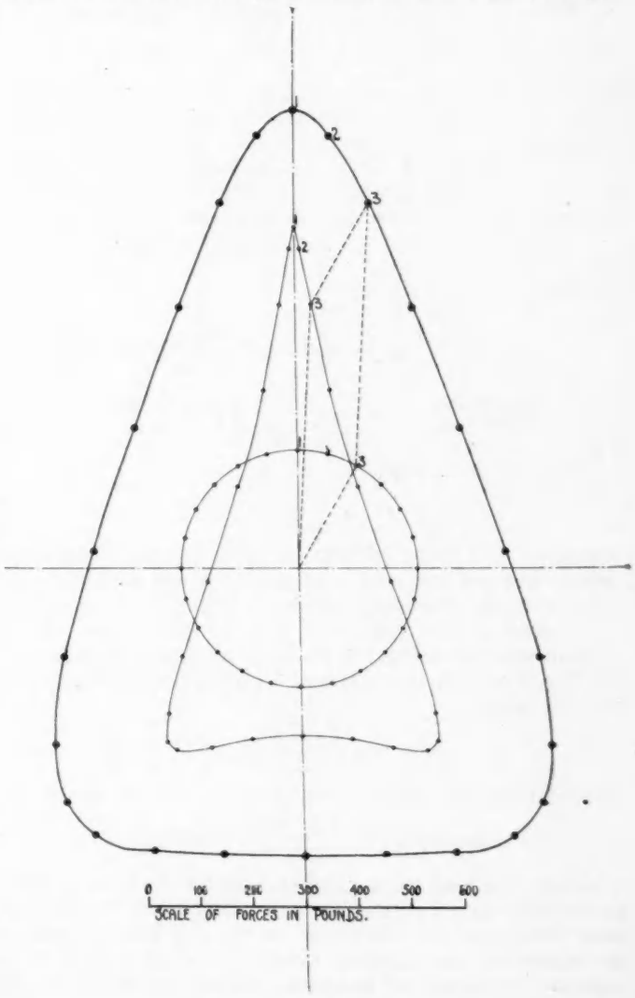


Fig. 9

loads are imparted to the main bearings in definite proportion, as emphasized in Case II. The partial loads ascertained according to the proportions derived from Fig. 6 are graphically represented on a larger scale in Fig. 8, where they are designated as $\frac{a}{c}$ and $\frac{c-a}{c}$ portions of the total crankpin load.

To determine the load on the end bearings, we have to combine components 1, 2, 3 and so on to 24 of the $\frac{a}{c}$ diagram with simultaneously acting component forces of $\frac{c-a}{c}$ diagram, i.e. with 13, 14, 15 and so on to 12. This yields the diagram of resulting forces which is marked "Resulting loads imparted on end bearings I and III."

Identically the same principle of combination must be followed in determining the loads on the center bearing. Since, however, the center bearing is affected by all loads on either of the four crankpins, it is evident that the resulting loads are all twice as large as those acting on the end bearings.

In the present case we have to consider further the centrifugal forces due to the crankpins and the adjacent crankcheeks. The crankpin and those portions of the adjacent crankcheeks which are not balanced in their own plane weigh for the engine under consideration about 6 lb. The centrifugal force due to this mass is 575 lb. at 1000 r.p.m. If we denote this centrifugal force by C we find with reference to Fig. 6 that main bearings I and III each receive the partial loads:

$$L_e = C\frac{a}{c} - C\left(\frac{c-a}{c}\right) = C\left(\frac{2a-c}{c}\right)$$

Substituting the dimensions given in Fig. 6, we obtain

$$L_e = 575 \times \frac{2 \times 9\frac{3}{8} - 13\frac{1}{2}}{13\frac{1}{2}} = 225 \text{ lb.}$$

Again, the load on the center bearing is twice as large as the load on either end bearing; hence 450 lb. We can now determine the total load on the end bearing, which by virtue of the existing symmetry at the same time represents one-half of the total load acting on the center bearing.

In Fig. 9 we recognize the triangular thin-line diagram as the one representing the loads imparted by connecting-rods I and II, respective III and IV on the end bearings, while the concentric circle represents the above determined centrifugal force of 225 lb. If corresponding forces of these two diagrams are combined in proper phase as indicated by dotted lines we obtain the final resulting forces acting on the end bearings. The resulting diagram in heavy lines shows a maximum load of 875 lb., a minimum load of 385 lb., and by summation we obtain the average load of 600 lb. While these loads have direct reference to the two end bearings we can find from them the loads on the center bearing by simply multiplying the former by two. This gives a maximum load of 1750 lb., a minimum load of 730 lb., and an average load of 1200 lb.

Case IV In this case we have to deal with the forces due to the gaseous mixture as well as with centrifugal and inertia forces. While I do not underestimate the difficulty of determining exactly the forces acting during the expansion and compression strokes, it is also certain that a fair estimate of these forces can be derived from the diagram shown in Fig. 10. This has been designed to conform as nearly as possible with indicator diagrams as known from actual practice. It represents a total of 1040 ft-lb. work, which in case of a four-cylinder engine when running at 1000 r.p.m. would mean

$$\frac{1040 \times 4 \times 500}{33{,}000} = 63 \text{ indicated hp.}$$

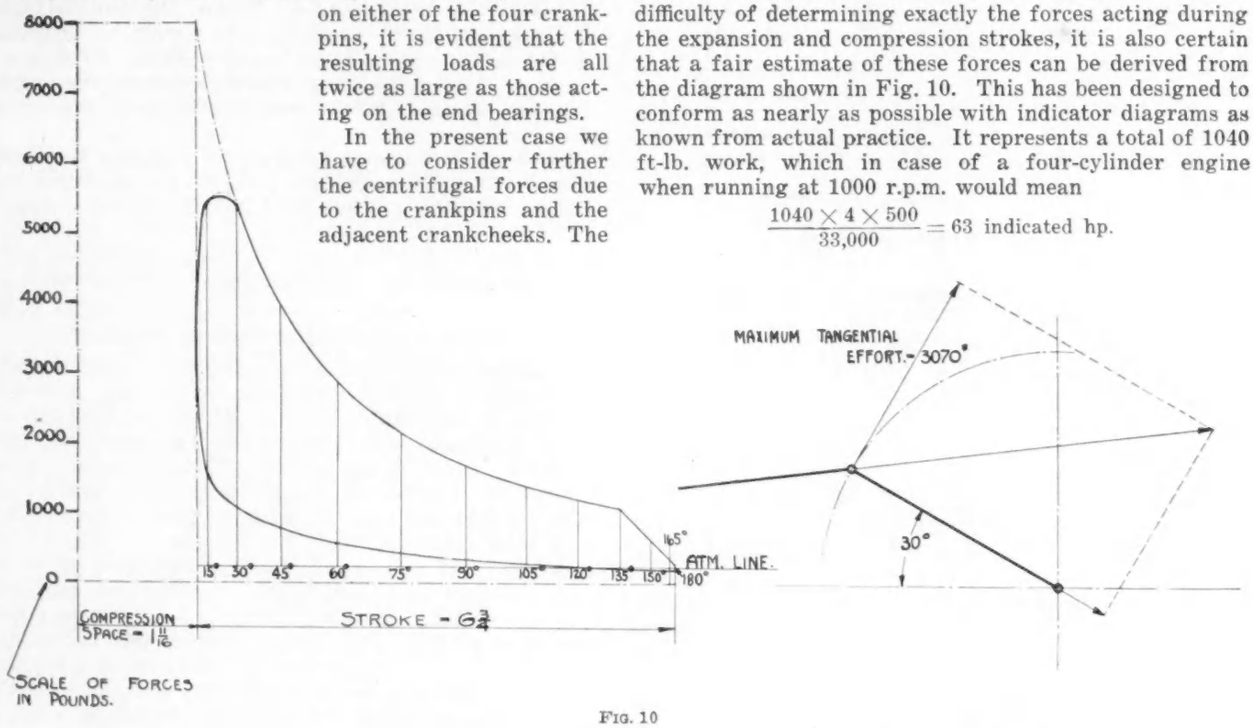


FIG. 10

If we allow about 14 per cent for engine friction, we obtain an effective output of 54 hp. This in turn corresponds to a mean effective pressure of 100 lb. per sq. in. of piston area. This may be somewhat higher than that generally obtained with truck and tractor engines; it is, however, less than the rather desirable standard set by aircraft engines which we endeavor to approach. One hundred pounds may therefore be chosen, not only because it is an even figure but because it is what we hope to obtain from engines in the future.

With this mean effective pressure as a basis it may be mentioned that the horsepower output at 1000 r.p.m. can be determined for any similar engine by the simple formula:

$$HP = \frac{b^2 s n}{10}$$

where b = bore in inches
s = stroke in inches
n = number of cylinders

The various pressures due to the gaseous mixture as taken from Fig. 10, together with the inertia forces, as well as certain horizontal components due to the angularity of the connecting-rod, are represented graphically by the irregular thin-line diagram, Fig. 11. It is of course evident that for the expansion stroke we find forces of considerable magnitude, while for the next three strokes the inertia forces are prevailing. This accounts for the reappearance of the same force diagram that we used in Fig. 7. The concentric circle shown in Fig. 11 represents the centrifugal force acting on the crankpin. If we now combine corresponding forces as before, we obtain the total load on the crankpin as represented by the heavy-line diagram.

From the latter we obtain the following characteristic loads:

Maximum = 4075 lb.
Minimum = 530 lb.
Average = 1230 lb.

These loads are imparted to the main bearings in proportion $\frac{a}{c}$ $\frac{c-a}{c}$. These partial loads are represented

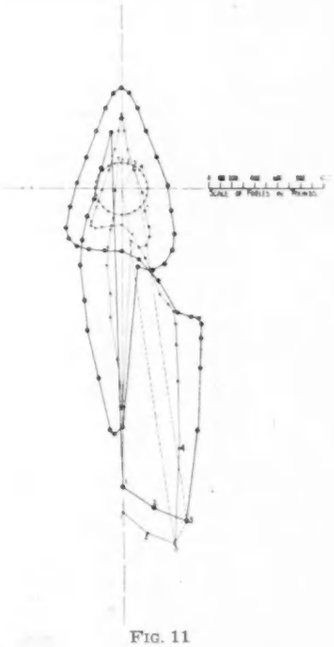


FIG. 11

in Fig. 12. Now to obtain from these the load on the end bearings we have to combine forces 1, 2, 3 and so on to 24 of the $\frac{a}{c}$ graph with forces 13, 14, 15 and so on to 1 of the $\frac{c-a}{c}$ graph. This yields the irregular thin-line diagram shown in Fig. 13. If the resultant forces so obtained are now combined with the centrifugal forces shown in the same figure, we obtain the heavy-line diagram which represents the resulting forces acting on the end bearings.

The characteristic loads obtained from this diagram are:

Maximum = 2945 lb.
Minimum = 380 lb.
Average = 1000 lb.

To obtain the loads on the center bearing due to crankpins 1 and 2, we have first to combine forces 1, 2, 3 and

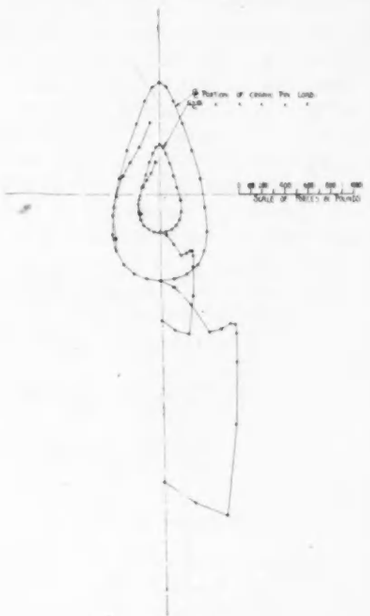


FIG. 12

so on to 48 of the $\frac{c-a}{c}$ diagram with 13, 14, 15 and so on to 1 of the $\frac{c}{a}$ diagram. This yields the diagram shown in Fig. 14. This diagram also represents the forces on the center bearing due to crankpins 3 and 4. We must however bear in mind that the latter are in phase 360 deg. behind the former. If we therefore combine forces 1 to 24 of the diagram in Fig. 14 with forces 25 to 48 of the same diagram, we obtain the irregular thin-line diagram shown in Fig. 15.

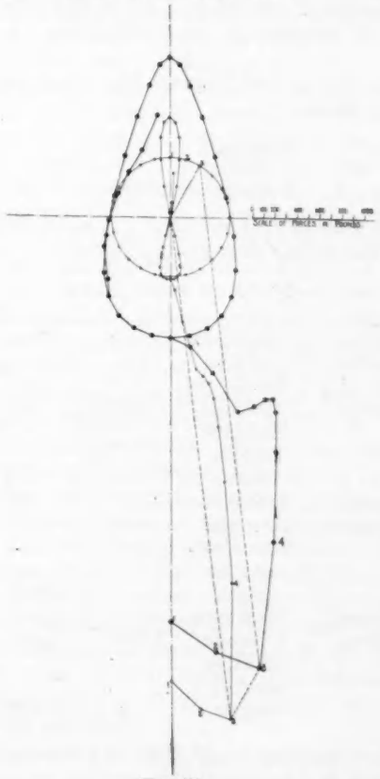


FIG. 13

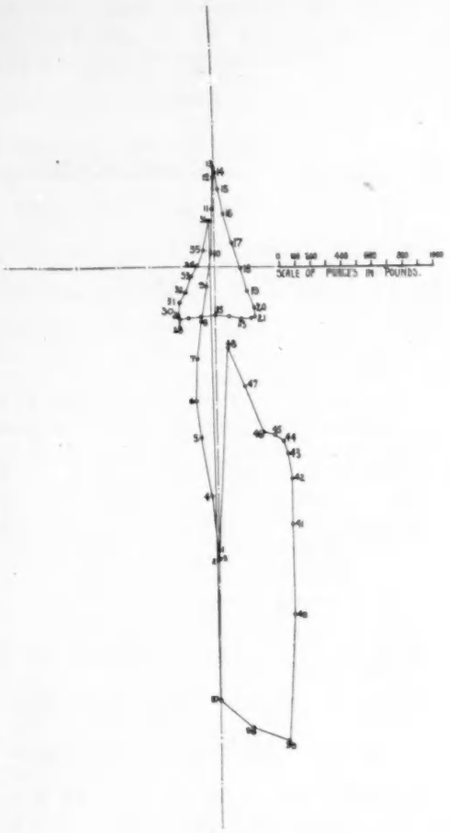


FIG. 14

If these forces are in turn combined with the centrifugal forces also shown in Fig. 15, a final diagram is obtained which represents the total load on the center bearing.

We obtain from this diagram the following characteristic bearing loads:

Maximum = 2690 lb.
Minimum = 580 lb.
Average = 1500 lb.

It may now be mentioned that the same force diagram is obtained for either firing order 1-3-4-2 or 1-2-4-3.

TABLE I—LOADS ON VARIOUS ENGINE BEARINGS

Running condition of engine	Character of load	Load in Lb. Crank-pin	End bearings	Center bearings
Low speed ...	Maximum	5,200	3,600	3,600
Full power ...	Average	663	663	1,326
	Relative bearing length	1	1	2
High speed ..	Maximum	1,415	875	1,750
Zero power ..	Average	940	600	1,200
	Relative bearing length	1	0.64	1.28
High speed...	Maximum	4,075	2,945	2,690
Full power ...	Average	1,230	1,000	1,700
	Relative bearing length	1	0.812	1.380

The various bearing loads thus far obtained are compiled in Table I. In this table certain relative figures are also given representing the different bearing lengths. The crankpin length has been taken as unity. These relative figures presuppose that the crankpins and the main bearings are of equal diameters, which is considered good practice for three-bearing shafts.

From the first group of forces pertaining to low engine speed and full horsepower output we note that the effective lengths of the crankpin, the end bearings and the center bearing should be in proportion 1 to 1 to 2 respectively. From the second group of forces we note that for high engine speed and zero power output the effective bearing lengths should be made in proportion 1 to 0.64 to 1.28. Finally, for high-speed and maximum power output requirements the bearing lengths should be made in proportion 1 to 0.812 to 1.380.

To pay adequate attention to the various factors given in Table I means to compromise. For instance, the engine under consideration will run at high speed, nearly 1000 r.p.m., about 80 per cent of its life, whereby it develops power varying from zero to maximum output. The limiting conditions are Cases III and IV. The bearing lengths required to conform with this running condition are the mean of the lengths determined for the limiting cases; hence,

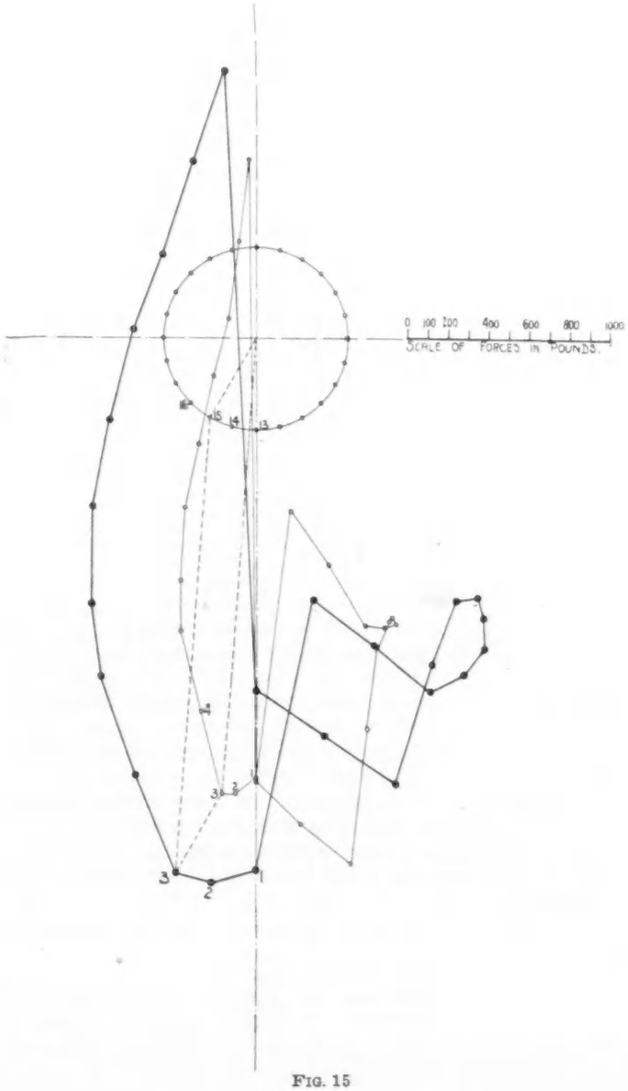


FIG. 15

$$\text{Relative end bearing length} = \frac{0.64 + 0.812}{2} = 0.726$$

$$\text{Relative center bearing length} = \frac{1.28 + 1.38}{2} = 1.33$$

We are at present concerned with the problem of minimizing the unavoidable wear and preventing uneven wear which cause unnecessary stresses in the structural parts. This requires that adequate attention be given also to the remaining 20 per cent of the engine's life during which it is running at low speed and developing full power for acceleration and hill-climbing, as investigated in Case II. This consideration elicits the following final proportions:

Relative crankpin length = 1
Relative end bearing length =
80% of 0.726 + 20% of 1 = 0.78
Relative center bearing length =
80% of 1.33 + 20% of 2 = 1.46

Let us choose for our example an effective crankpin length of 2½ in. We then obtain end bearing length of

$$0.78 \times 2\tfrac{1}{2} = 1\ 15/16 \text{ in.}$$

and a center bearing length of

$$1.46 \times 2\tfrac{1}{2} = 3\tfrac{5}{8} \text{ in.}$$

The front end bearing should be lengthened about 5/16 in. to allow for the load, due to the timing-gears, whereas at least 1-in. effective length should be added to the rear end bearing to compensate for the effect of the clutch and the flywheel. Allowing further ⅛ in. for each fillet, we obtain the following compilation:

TABLE II

Bearing	Nominal length, in.	Allowance for fillets, in.	Other allowances, in.	Actual length, in.
Crankpin	2½	2 × ⅛ = ¼		2¾
Front end	1 15/16	⅛	5/16	2⅝
Rear end	1 15/16	⅛	1 1/16	3⅛
Center	3⅝	2 × ⅛ = ¼		3⅞

Some consideration may now be given to the diameters of the crankpins and the journal bearings. In Fig. 10 I have shown that the maximum tangential effort is 3070 lb. This force when exerted on crankpins I or III can be resisted only through forces set up in crankpins II and IV respectively. The lever arm on which the force of 3070 lb. acts is the distance between the centers of the crankpins. Consequently crankpins II and IV are subject to a twisting moment of

$$3070 \times 6\tfrac{3}{4} = 20{,}700 \text{ in-lb.}$$

The elastic limit of the crankshaft material may be taken as 80,000 lb. per sq. in. The factor of safety desired is 10. When denoting by d the diameter of the crankpin we have the following equation:

$$20{,}700 = \frac{\pi}{16} \times d^3 \times \frac{80{,}000}{10}$$

Hence $d^3 = 13.18$ or $= d = 2.36$ say 2⅜

Comparison of Results

Let us now compare our results with others advanced by a highly-esteemed authority. This authority states that "The average lengths for the three main bearings, taking the length of the connecting-rod big-end bearing as 1, are 1.21 for the front, 1.17 for the middle and 1.48 for the rear."

The reason that these results deviate considerably from the former is that they have been arrived at by measuring the bearings of a number of engines. It is a fact that of the engines measured only one or a few were nearest to the ideal. The influence of the greater amount of data not as good qualified results very much in the fashion of the distiller's formula: ½ gal. wine + ½ gal. water = 1 gal. of whatever is ordered.

Another rule of thumb reads that the crankpin diameter should be $0.4 \times b + \frac{1}{4}$ in. With this formula we would obtain for our engine a diameter of 2.05 in. By substituting this in our equation for d we can determine the factor of safety F. It is

$$20{,}700 = \frac{\pi}{16} \times 2.05^3 \times \frac{80{,}000}{F} \text{ or } F = 6.5$$

This is obviously too small for a part as important as the crankshaft.

The Discussion

David Fergusson:—The examples given by Mr. Burkhardt are very important in automotive engineering. There is a tendency among some manufacturers of motor trucks to abandon radius rods and torque rods. In following Mr. Burkhardt's reasoning closely we can see wherein designers are liable to get in wrong when trying to secure both propulsive effort and torque through the springs, thereby eliminating radius rods and torque rod. They will have to put extra weight into the springs to enable them to perform these two additional functions, and it is questionable policy to make a flexible member such as a spring perform the duty of a rigid member such as the conventional torque rod, especially as more weight must be added to the springs than is saved through the elimination of the torque rod.

There is great looseness of method in the design of motor cars and trucks, and faulty construction is in some cases due to the extreme haste with which these vehicles are put on paper and immediately afterward into production. Many laws of mechanics are lost sight of entirely, and we sometimes find a draftsman applying well-known laws without adequate knowledge of them. In one case recently, the fact that a hollow round shaft is stronger than a solid round shaft, for the same weight, was misconstrued by a would-be engineer, who recommended drilling a hole in a shaft that had proved to be weak to strengthen it, without changing its outside diameter.

There are cars and trucks constructed with the commonly termed Hotchkiss drive; that is, they do not make use of either radius rods or a torque rod. The apparent success of these may be due to the fact that all successful vehicles have a certain factor of safety in their parts, over what is necessary to take care of the load. It is this factor of safety that redeems many faulty constructions. The designer figures on a factor of safety of, say, 5. If his premises are wrong he may have only half of this, and while his truck may run satisfactorily in certain lines of work, it will never withstand the abuse that a truck having the full factor of safety would, and its life will be much shorter. Such a truck may give some degree of satisfaction if never loaded to its full capacity, or if never used on hilly roads. On the other hand, if used under severe conditions, it might break down and cause a fatal accident.

It is very essential that the full factor of safety be maintained. Whether this should be five or ten times

the working load depends upon the work the part must perform, and this varies in the opinion of different engineers. Again, the value of the factor of safety depends on whether it is taken in connection with the elastic limit or the ultimate breaking strength of the material. The best construction, from an engineering point of view, is that which gives the highest factor of safety with the least amount of material, and I believe that a motor truck should have both radius rods and a torque rod, or their equivalent.

In regard to crankshaft bearings, as Mr. Burkhardt has shown, examples taken from practice are often misleading. In many cases the bearings are almost twice as long as they should be, and the whole engine could be shortened up and thereby lightened, and at the same time stiffened. In other cases the bearings are too short, resulting in undue wear and necessitating frequent repairs. It is certainly good engineering to have those bearings properly proportioned, and so make the best use of the materials employed, otherwise we are not using proper methods of design.

MR. BURKHARDT:—I must agree with what Mr. Fergusson has said of the apparent success of vehicles embodying the Hotchkiss drive. I think the London omnibuses, which are minus the torque and radius rods and yet are doing their proper work day-in and day-out. But I must call attention to the fact that these vehicles are not encountering as many obstructions as, say, a contractor's truck. The omnibus can have springs designed to suit city pavements; the truck must be a good running vehicle whether it is carrying a light load of eggs or a 50 per cent overload on poor roads. In order that springs shall stand up under all kinds of loads we must maintain a definite factor of safety.

The deflection of the springs is a direct function of the load on the truck. With the Hotchkiss drive we must provide for much extra load, and we dare not exceed with this combined load the safe load on the springs. A spring resilient enough to carry a light load of eggs safely would be unsuitable for carrying a heavy load on bad roads, and a spring stiff enough to carry a heavy load over bad roads would be unsatisfactory for carrying the lighter load. The safe speed of motor vehicles is a direct function of their suspension; hence vehicles with radius and torque rods can be operated at higher speed than those without these useful members.

ROBERT W. CUNDALL:—I wonder if there is a force that Mr. Burkhardt has not taken into account in his illustrations which causes strain on bearings? How does the bearing unit pressure compare with the breaking stress of the shaft? In an engine, are large bearings provided to give strength or to sustain pressure rather than stresses?

MR. BURKHARDT:—No important forces have been neglected in the investigation. Bearing loads are important. We can, however, as emphasized in the paper, determine the shaft diameter so that a certain fiber stress shall not be exceeded. Then we can lengthen the bearing until a certain specific bearing pressure is attained. Another point which needs mention is that the life of a bearing is a function of pressure and velocity. For this reason it is best to keep the diameter small. On the other hand, large diameters stiffen the shaft and reduce vibrations. I spoke of a factor of safety of 10. This factor is considered good practice.

E. T. LARKIN:—Regarding the crankshaft, we may enter into diverse calculations and still obtain a bearing so short that it will not maintain lubrication under the heat conditions met in a gas engine. It is necessary to have a longer bearing than the calculations show to maintain proper oil films. I have found cases where it proved to be better to provide three large bearings than five small ones on a crankshaft.

MR. BURKHARDT:—A three-bearing shaft is quite satisfactory for low speeds. For higher speeds the five-bearing shaft is more satisfactory, because the deflection of a shaft causes vibrations. Both are considerably reduced by shortening the distance between the bearings.

C. M. MANLY:—I think Mr. Burkhardt is in error regarding the raising up of the front end of the truck. It seems that the truck must be backing up to have this occur. Regarding the formation of the springs in the Hotchkiss drive, I cannot conceive that one would be concave and the other convex. I cannot think that it would be likely to occur in vehicles in general that the torque at either end of the springs would not be greater than the load. Assuming that we have a load of 14,000 lb., the springs would have to take 14,000 lb., and one-fourth of 14,000 lb. at each end of each spring would be 3500 lb. It is not probable that there would be a load of 3500 lb. due to the torque at each spring end. I have found this would cause a turning up of the axle.

MR. BURKHARDT:—The front end of a motor vehicle has a tendency to leave the ground when the vehicle is proceeding forward, not backward. If we attach a drawbar high enough on the chassis, the front end will rise, not the rear end. If a spring is flat when loaded with, say, 3500 lb. at each end, it will assume a convex curvature the moment an additional load is imposed on it. This is bound to take place.

W. M. CORSE:—Tractors have a decided tendency to rear on their hind wheels and overturn backward.

MR. BURKHARDT:—This certainly is the case. A device designed for a popular tractor to prevent it from overturning is being put on the market.

F. W. DAVIS:—It is usually very poor practice to assume that the average design is ideal. The matter of bearing sizes is one that has been left to arbitrary methods. The practice is to add the bearing lengths, divide by the number of engines, take the average, and assume that the result is correct. The manufacturer of trucks is constantly studying the details of design being produced at the present time, but we must bear in mind that present design still needs a great deal of study to produce the most economical results. Trucks should operate 20,000 or 30,000 miles before being taken down and overhauled, and after being thoroughly overhauled should be good for 20,000 or 30,000 miles more. This can be accomplished only by having the design right and the parts properly made and fitted in the first place.

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Fuel Economy of Automotive Engines

By Dr. H. C. Dickinson[1] (*Member*)

Annual Meeting Paper *Illustrated with* Photographs and Curves

THE subject of fuel economy in automotive engines has been of such secondary importance as to appear mainly of academic interest. Fuel costs in this country have not yet become of primary importance in maintenance of passenger cars and seldom so in the operation of commercial vehicles. Questions of first cost, reliability, flexibility, and in the case of passenger cars, ease and comfort of operation, in other words, luxury, have been of far greater commercial importance.

There has been a decided though gradual increase in the importance of fuel costs in the last few years. This is partly due to the increase in the cost of gasoline relative to that of other items in the total bill for operation of motor vehicles, and partly to the stabilization of the industry, which always leads to more and more careful consideration of all items of expense.

That the relative importance of fuel costs, particularly as regards commercial vehicles, will increase at a growing rate from now on is inevitable. This is readily seen on a careful analysis of the situation as to fuel supply. The extent and success of the automotive industry will depend upon the amount and price of available fuel, and the cost per ton-mile or ton-mile per hour of transportation.

This then raises the questions which the automotive engineers must face, and face immediately: (1) What are to be the available fuels from the point of view of the engine designer? and (2) How many ton-miles or ton-miles per hour can be obtained from the total available supply?

The Fuels of the Future

The answer to the first question, i. e., what are to be the available fuels, will depend upon the possible flexibility of automotive engines as regards the use of less volatile or perhaps impure or mixed fuels not now available. Of course, alcohol, benzol and shale-oil distillates may add increasingly to the supply of fuel of approximately the present grades of volatility; yet it is imperative that the industry should fully appreciate the necessity of much further development in the use of less volatile fuels and perhaps of special fuels to meet future requirements. The properties of fuels at present recognized as important and subject to specification and test are as follows:

(a) Volatility, determined by distillation. The characteristics of the low boiling fractions determine the ease of starting of any given engine. The characteristics of the high boiling fractions indicate the tendency to incomplete combustion and to contamination of lubricating oil.

(b) Resin values determined by gumming test which determine the liability of the fuel to leave objectionable gummy deposits in the carbureter or on valve stems, etc.

(c) Heat of combustion in British thermal units determined by a combustion calorimeter. The heat of combustion determines the total available energy supply in any given fuel. Differences between different gasolines do not exceed 2 or 3 per cent. Fuels of widely different heats of combustion (gasoline and alcohol) give corresponding differences in pounds per horsepower-hour. As between different gasolines in use, these relative differences are not apparent.

(d) Presence of unsaturated hydrocarbons determined by chemical treatment specified by the Bureau of Mines. The presence of these compounds does not affect the power-producing qualities of the gasoline so far as is at present known.

Other properties not commonly determined by test but which may be important are as follows:

(a) Vapor pressure which is closely related to volatility is probably important as regards the starting qualities of fuel.

(b) The product of vapor pressure by fluidity offers a means of estimating the occurrence of different constituents in a gasoline.

(c) Viscosity which usually varies with the temperature and composition of the fuel. Changing viscosity affects the metering characteristics of most carbureters.

(d) Saturation, pressures and temperatures for fuel-air mixtures in combining proportions. These relations may be important in determining the temperatures at which complete vaporization of the fuel in the intake can be secured.

(e) Rate of flame propagation. It is important in the selection of fuels for high-speed operation and also determines to some extent the thermal efficiency which can be obtained.

(f) Detonation is of importance in determining the maximum compression pressures at which any given fuel can be successfully used.

(g) The products of combustion occurring during the process of combustion, if determined, would probably throw light upon the causes of detonation and help to explain the different characteristics of different fuels.

Engine characteristics which have a bearing on the behavior of different fuels are as follows:

(a) Compression ratio which is limited by the tendency of the fuel to preignite or to detonate. The production of fuels which resist preignition or detonation would permit of considerable increase in compression ratio and corresponding increase of thermal efficiency. (See Fig. 1)

(b) The design and dimensions of the explosion chamber or the ratio of surface to volume affect the tendency of a fuel to preignite as they do the thermal efficiency of the engine.

(c) Localized hot spots occurring, for instance, on spark-plugs, piston heads or valves, affect preignition.

[1] Bureau of Standards, Washington.

(d) Engine speed in revolutions per minute. The speed at which an engine can be run with satisfactory thermal efficiency depends upon the rate of flame propagation and other characteristics of the fuel.

Some problems which are of interest in the study of fuels are as follows:

(a) The effect of varying fuel composition on brake thermal efficiency of engines of different types. Some measurements of this kind are available for maximum load conditions, but scarcely any for engines operating at low throttle.

(b) The phenomenon of detonation which occurs persistently with some fuels and much less so with others is of prime importance. Its cause and possible remedies should be given additional study.

(c) The commercial development of fuels which will permit of increased compression pressures. Such fuels as cyclohexane and benzol-gasoline mixtures offer a promising field of investigation.

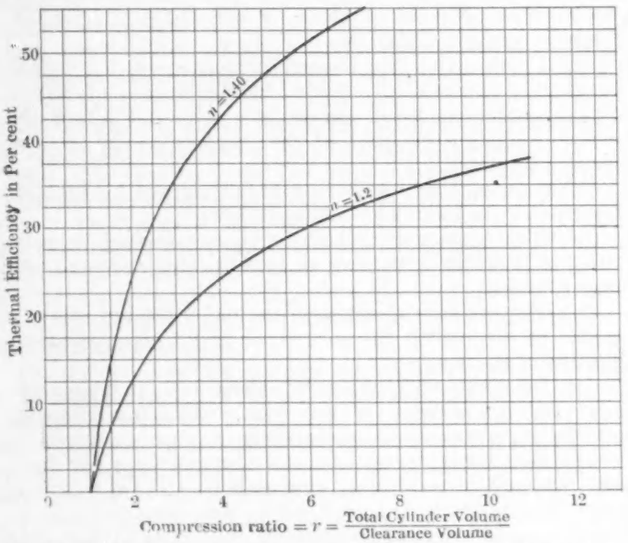

FIG. 1—RELATIONS BETWEEN THERMAL EFFICIENCY AND COMPRESSION RATIO IN AN INTERNAL-COMBUSTION ENGINE

Another question which appears to the writer worthy of careful consideration is this: In the use of fuels of a wide range of volatility, will the best over-all economy be secured by developing apparatus to use a single very heterogeneous fuel such as would be represented by a mixture of gasoline, kerosene and perhaps heavier fractions; or will this same end be best attained by developing two or more distinct types of appliances, and consequently the marketing of two or more distinct and semi-standardized fuels? The more volatile of these would not be used to any extent in appliances fitted for the less volatile grades on account of cost, fire risk or other causes.

There is much to be said on both sides of this question, which should be settled as a matter of fixed policy by the automotive and the oil industries jointly. If these industries are allowed to pursue their course of natural development without such a directing policy the ultimate solution is likely to be long delayed and will result in great expense to all concerned.

THE LINES OF DEVELOPMENT

The present trend of development seems to point to the use of two or more fuels. We have as semi-standardized products, gasoline and kerosene, and a trend of development toward devices intended specifically to utilize one or the other. While most of the kerosene devices will still use gasoline as well or better than kerosene, this may be attributed to the fact that most of these devices are direct lineal descendants, so to speak, of gasoline devices and to the fact that the trend of commercial gasoline has been to encroach more and more on the kerosene field. If future carbureters are developed and widely adopted which will handle kerosene and heavier distillates better than they will gasoline, there will be a strong tendency to make gasoline and kerosene more distinct in character than at present, i. e., there will be less necessity of including the heavier fractions in gasoline or passenger car fuel, as they might be marketed at nearly the same price in the heavier grade of fuel.

The advantages to be gained by this line of development are as follows:

(a) It would permit the unrestricted use of most of the present existing carburetion equipment for its entire useful life, since there would then be no necessity for any further considerable reduction in quality of gasoline.

(b) It would permit a permanent use of the more volatile fuels for those types of service where convenience, flexibility or luxury are important, such as airplanes and passenger cars, and of a less volatile and somewhat cheaper and much safer fuel for most commercial purposes.

(c) It would offer a real advantage from the engineers' standpoint in not calling for the design of all equipment to meet the most difficult carbureting condition. There is no question that the use of kerosene and heavier fuels in engines of the present type presents to the engineer a difficult problem which is likely to be solved much more satisfactorily for commercial cars than for passenger cars. The heating of the inlet charge which at present appears essential to the use of heavy fuels, necessarily decreases engine power, thus requiring a larger and therefore heavier engine to deliver the same maximum power. This is accompanied by increasing friction losses which are extremely important at the average light-load conditions obtaining in passenger cars. The average engine load is probably much nearer the maximum in all commercial vehicles.

(d) The quality of two fuels could probably be maintained more nearly uniform than that of a single fuel, as there would be greater opportunity with two grades for the refiner to adjust the distribution of the fractions of his total product to accord with the demands of the user.

Offsetting these advantages made possible by the use of two distinct types of fuels, there are decided advantages to be expected from the adoption of a single fuel for all automotive engines:

(a) The cost of production and distribution of a single fuel would be less than that of two fuels.

(b) All automotive equipment would eventually be standardized to handle the same universal fuel.

The foregoing discussion has been based on the present general type of engine, i. e., the four-stroke Otto cycle, constant-volume engine, water-cooled, and supplied with throttle-controlled, carbureted mixture. That this almost universal type may be replaced by something else in the interest of fuel utilization is not beyond the bounds of possibility. Other types, such as the Diesel, with fuel injection, are better adapted to the use of heavy fuels, are more flexible in the kinds of fuel which they will use, and may offer other advantages in economy. If

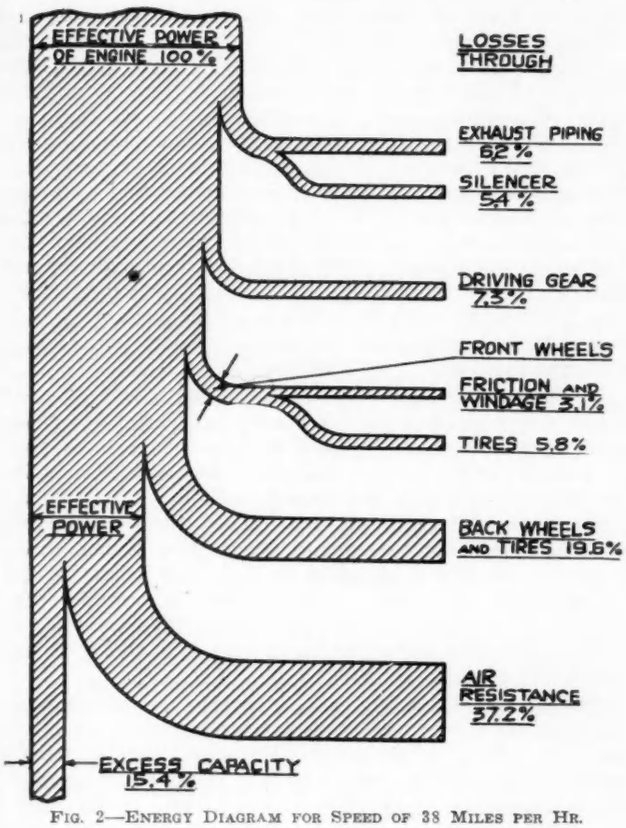

FIG. 2—ENERGY DIAGRAM FOR SPEED OF 38 MILES PER HR.

a radically different type of engine should be developed along these or any other lines, or if for instance a steam engine, some of which show thermal efficiencies equal to that of present automobile engines, viz., above 20 per cent, or a combustion turbine, should ultimately be widely adopted, the advantages of a single fuel would be increased.

FUEL ECONOMY

The second main question, i. e., how many ton-miles or ton-miles per hour, or tons drawbar-pull miles, can be secured per gallon of fuel, may best be considered by a general survey of the energy distribution in the operation of automotive appliances.

The automotive vehicle, whether it be passenger car, truck or airplane, is essentially an appliance for transforming stored heat energy into useful work in the form of transportation in ton-miles or ton-miles per hour. In tractors the useful work may be represented by ton drawbar-pull miles. It is interesting to note that trucks and passenger cars deliver approximately the same number of ton-miles per hour for the same heat supplied on the basis of the total weight of the machine.

TABLE OF FIGURES

Trucks	0.57 ton-miles per hr. per hp.
Passenger cars	0.47 ton-miles per hr. per hp.
Airplanes	0.58 ton-miles per hr. per hp.

Granting that the object to be gained, so far as fuel is concerned, is the maximum number of ton-miles, or for some purposes ton-miles per hour, per unit of available heat under average operating conditions, it is of interest to arrive at some estimate as to what becomes of the heat supplied by the fuel burned under these conditions.

Fig. 2 represents the average of a number of familiar published analyses of heat distribution in passenger cars at approximately full load and most favorable speed with most favorable road surface. This may serve as a basis for discussion of the various items involved.

Fig. 3, presented for illustration, gives the results of experiments with an Hispano-Suiza aeronautic engine tested in the Altitude Laboratory of the Bureau of Standards.

The following table gives the heat distribution for motor vehicles: (Some of the figures for passenger cars have been estimated)

	Full load and most favorable laboratory adjustment, per cent	Average load and speed laboratory adjustment, per cent	Average load and speed, average operation adjustment, per cent
Heat supplied	100	100	100
Cooling water	36	38	48
Exhaust	36	39	48
Engine friction	6	13	13
Brake thermal efficiency	22	10	6

Of the available power of the engine, also of the heat supplied, the distribution is somewhat as follows:

	Good practice		Average practice		Bad condition	
	Engine power, per cent	Heat supplied, per cent	Engine power, per cent	Heat supplied, per cent	Engine power, per cent	Heat supplied, per cent
Muffling	9	2.0	10	1.0	10	0.6
Driving gear	12	2.6	15	1.5	18	1.1
Tires (on best roads)	23	5.1	30	3.0	35	2.1
Road surface (added load)	0	0	5	0.5	12	0.7
Useful power	56	12.3	40	4.0	25	1.5

Let us consider these items individually, beginning with the brake thermal efficiency.

BRAKE THERMAL EFFICIENCY

The present brake thermal efficiency of the best aeronautic engines is roughly 25 per cent running up to perhaps 28 per cent or a little higher in extreme cases at full load and the most favorable speed. The maximum thermal efficiency of the modern automobile, truck or tractor engine will seldom exceed 20 per cent under full load and most favorable speed conditions. The greater part of all gasoline is, however, consumed in engines running under very much less favorable conditions.

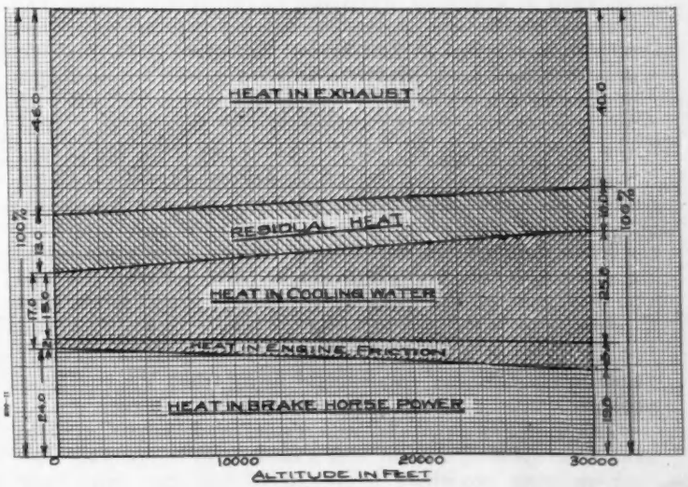

FIG. 3—HEAT DISTRIBUTION AT VARIOUS ALTITUDES IN A 150-HP. HISPANO-SUIZA AIRCRAFT ENGINE

If it is assumed that the average passenger car in this country is capable of a road speed of 45 miles per hr. and is operated at an average speed of 20 miles per hr., then the tractive load in pounds is probably not far from one-fourth maximum tractive load and the engine speed is about one-half the rate. The average car as now built is, therefore, necessarily being operated under conditions which absolutely preclude an engine brake thermal efficiency exceeding something between 10 and 15 per cent; probably very much nearer 10 per cent than 15 per cent.

This figure again represents not what the average car is doing, but simply the best that it could do under the average speed and load conditions if supplied at all times with the most efficient fuel-air mixture, which unfortunately is seldom the case. How far the present average carbureter adjustment is from the best possible one is

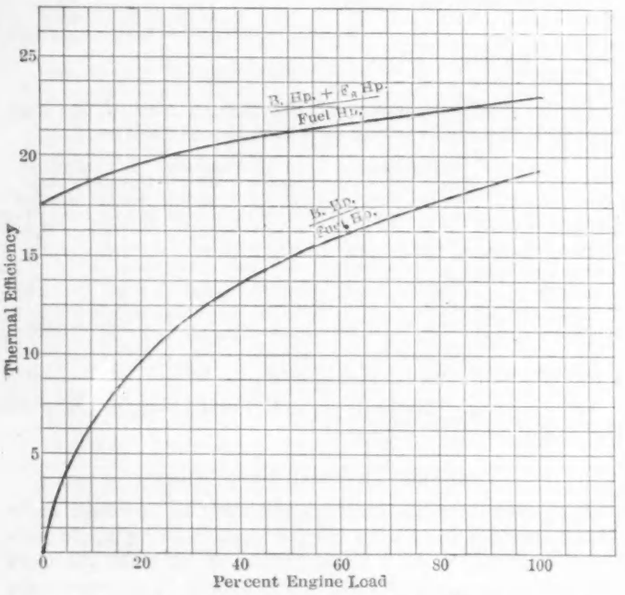

FIG. 4—BRAKE THERMAL EFFICIENCY OF A CLASS B TRUCK ENGINE OPERATING AT 1000 R.P.M.

not now known. As an illustration of what may be the difference between the possible and actual average fuel consumption, Fig. 6 gives "miles per gallon" as measured on a standard Ford engine mounted with a fan load, adjusted to give a speed corresponding to 40 miles per hr. car speed at full load. Car-speed load relations are computed from previous data on power requirements of cars on a level road. These results are in accord with what we know of the performance of cars of this kind, and are probably representative of what is happening with Ford cars on the road. And Ford cars are responsible for the consumption of a large share of the gasoline used.

Briefly stated, the average passenger car is running on an average mixture ratio somewhere between 25 and 50 per cent richer than is necessary, with consequent increase in carbonization and in lubrication difficulties, and with no attending advantages except possibly greater ease in starting and quicker get away when the engine is cold.

The scores of "pills," "improvers," and "dopes" sold to the unsuspecting public and guaranteed to increase the car mileage anywhere from 20 to 100 per cent bear eloquent testimony to the failure of passenger vehicles in particular to reach their maximum fuel economy. There is, of course, no known substance commercially available which can be mixed with gasoline in the proportion of 1 in 5000 or even 1 in 500 with any significant effect on engine power. Probably no such substance exists. Whether any substances in such small amounts can reduce the deposition of carbon is difficult to prove conclusively, but there is no reliable evidence that even this can be accomplished. Yet the engineers must face the incontestable fact that fuel improvers are sold and that changes in engine condition, carbureter adjustment and carefulness of the driver, etc., which accompany their use, do account for actual increases in average mileage per gallon, even when full discount is made for the psychological element.

In the recent *New York Herald* 1000-mile track and road test, neglecting the necessary uncertainties of any such test, some eleven cars did actually attain an average mileage of 19.8 miles per gal., and these same cars with modified attachments and adjustments made an average mileage of 28.6 miles per gal. This was accompanied with no significant decrease in acceleration or flexibility, if the records are to be taken at their face value. While no engineer could accept without qualification the conclusions drawn from a test of this kind, the figures given illustrate at least the possible differences in fuel economy which can occur in practice.

One cannot escape the conclusion that the average car could be made to cover at least 20 per cent more miles per gallon than it does today. In other words, sufficient engineering skill, if applied at this point, could conceivably increase by 20 per cent our available fuel supply; or, in other words, permit an additional 1,000,000 cars to operate on the present gasoline consumption.

The demand for cars characterized by easy starting and quick get-away with a cold engine, is responsible for a large part of this excess fuel consumption; and considered from the point of view of the automobile industry when facing a probable limitation of fuel, this ease of starting is expensive at the price. The development of better means of starting and warming an engine seems to have been neglected, except as regards convenient means of turning the engine over. The writer believes that this is an undeveloped field in which a reasonable amount of engineering ability might yield large returns to the successful inventor, and incidentally benefit the whole industry enormously by removing one of the main obstacles to better average fuel economy. However, the owner and the garage man are not responsible for all the fuel waste.

The subject of carburetion opens a field for unlimited discussion. In spite of the enormous amount of development work done in this field, the art of metering and mixing fuel and air, even considering commercial gasoline alone, has not kept pace with the development of the engine and the changing quality of gasoline. There is no doubt that a more nearly universal application of carefully worked out engineering laboratory tests on all carbureters, over their full range of performance, would lead to decided improvements and perhaps to the elimination of some designs which cannot be made to give uniform results. Without attempting to discuss this field of design, the writer ventures to urge the importance of at least the abolition of the present common practice of supplying carbureters with a wide range of adjustment which the ordinary garage mechanic or the owner can manipulate to suit his own fancy.

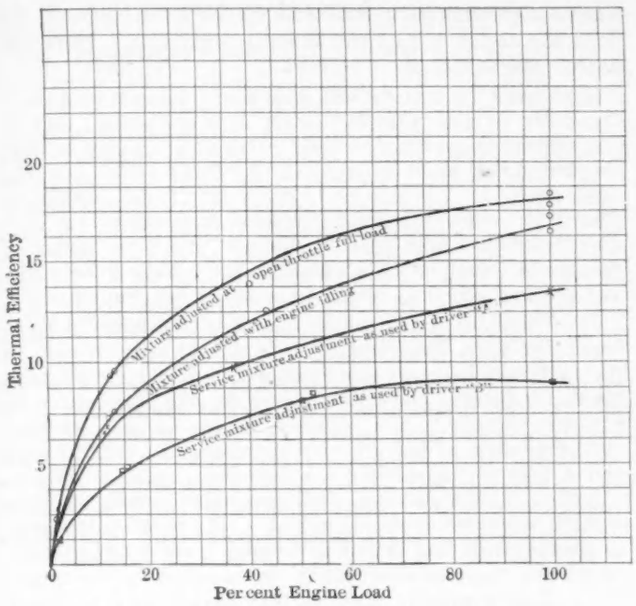

FIG. 5—BRAKE THERMAL EFFICIENCY OF A FORD ENGINE

The carbureter, so-called, is essentially a device for metering and atomizing fuel and mixing it intimately with the measured quantity of air required by the throttle opening. So far as metering alone is concerned, there is no serious difficulty in producing a non-adjustable carbureter for all kinds of service. The only difficulties occur at very light loads and with extreme temperature changes. Numerous successful methods of metering properly at low throttle are in use. The effect of changes in temperature or quality and consequent changes in viscosity of the fuel can be minimized by the use of types of metering orifices in which the rate of discharge is least affected by viscosity.

As regards atomizing and mixing, the adoption of a non-adjustable design presents no serious difficulties. The general adoption of the best available non-adjustable carbureters would effect a very important saving in fuel. A more general adoption of accurate laboratory methods for development tests may be depended upon to bring out designs which will meet all requirements with still greater economy of fuel.

EXHAUST LOSSES

The heat in the exhaust gases represents with complete combustion in general about 40 to 45 per cent of the total heat of the fuel burned in the cylinders. If the fuel charge is *completely* burned early in the power stroke, the exhaust heat is determined by the total heat of the fuel burned, the compression ratio, and the loss to the jacket. With perfect carburetion, including both vaporization and mixing of the fuel and air, and with proper timing of ignition, this loss is a minimum.

In practice, however, the atomization of fuel in the carbureter is usually not complete enough to permit of complete combustion early in the power stroke and the exhaust usually contains considerable heat due to delayed combustion of some of the fuel, as well as considerable unburned or partially burned fuel. These losses probably represent the largest remediable waste of fuel in automotive appliances. If this waste alone could be eliminated, certainly at least 500,000 additional passenger cars or their equivalent, possibly twice this number, could be operated on the gasoline which would be saved.

COOLING WATER

The cooling of cylinder walls is apparently essential, but the loss varies so much that a careful study of its causes is important. Unlike losses in the exhaust, it is subject mainly to mechanical, not therodynamic, limitations, and, in theory, at least, might be greatly reduced.

Transfer of heat from the hot charge to the cylinder walls takes place both by conduction and by radiation from the hot gases to the cooler cylinder walls. As the gases themselves are transparent to radiation, the amount of heat received per unit area of cylinder wall depends not only on the temperature but on the depth of the radiating gas charge or, in other words, on the cylinder volume.

The percentage loss to cooling water for a given mean effective temperature of charge depends upon turbulence, cylinder design and dimensions, piston speed and cylinder wall temperature. The latter is less important than might appear, since the effective temperature of the charge is so much higher than that of the walls (the difference being probably well over 2000 deg. fahr.) that differences of 100 to 150 deg. such as may occur in cylinder wall temperature are not very important as regards jacket water losses.

Three possibilities for a radical decrease in cooling jacket losses are:

(a) Reduction in the ratio of surface to volume in the combustion chamber.

(b) Reduction in the mean effective temperature in the cylinder without too great loss of efficiency of the cycle.

(c) The operation of engines with cylinder walls very much hotter than at present.

As has been pointed out above, the walls would necessarily be very much hotter than is possible under existing conditions to offer any considerable advantage in reduction of jacket losses. However, a moderate increase in temperature may improve fuel economy and lubrication as well as prevent the deposit of fuel on the cylinder walls.

Reduction in mean effective temperature, on the other hand, offers some practical possibilities. For instance,

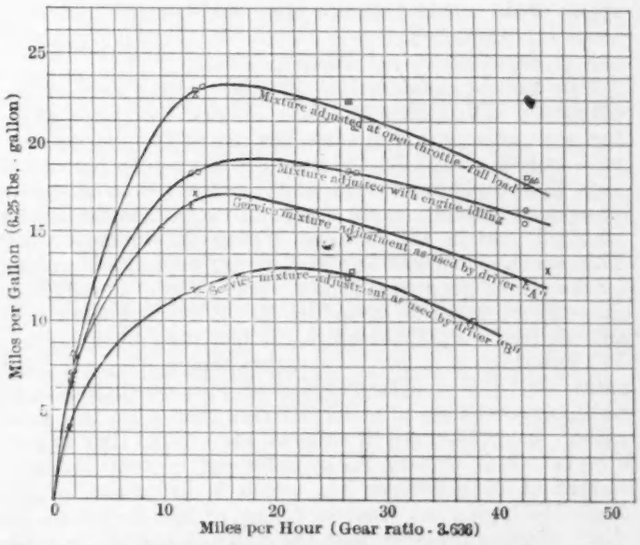

FIG. 6—CURVE OF FUEL CONSUMPTION AND SPEED FOR A FORD ENGINE USING VARIOUS MIXTURES

in fuel injection engines, direct and semi-direct types, the cycle efficiency might be maintained with very moderate temperature within the cylinders. The mechanical efficiency, however, tends to be low under these conditions.

Friction Losses

The friction losses in engines are usually from 10 to 20 per cent of the brake power developed by the engine, or from 2 to 4 per cent of the heat supplied. Any reduction in these losses, however, will increase the available power of the engine and permit the use of smaller units on account of the relatively large amount of power absorbed in friction at light engine loads. The friction losses comprise those due to (1) the work necessary to compress the charge from the intake pressure to that of the exhaust, (2) the friction of the reciprocating and rotating parts of the engine, the piston, valves, camshafts and crankshafts, and (3) the power necessary to drive the auxiliary apparatus, the ignition and lighting systems, the fan and water-pump, etc. Of these losses, that due to the compression of the charge is the most important, being in some cases as much as 50 per cent of the total friction loss.

The Discussion

F. C. Mock:—If we are discussing the problem of fuel economy with reference to fuel consumption in this country in the 5 or 6 yr. just before us, it is obvious that we must take into consideration the operation of engines already built or those which will be built within the next 2 or 3 yr., according to present or older designs. Improved design will not have a great effect upon the general fuel consumption of the country for several years.

As regards tire and road surface, driving gear and friction losses, I have regularly followed the practice of estimating the power required to drive a car by noting the time required for deceleration while coasting. This time of deceleration is an indication of the road and mechanical friction of the car per unit weight, and I have been surprised to note that a great many different cars, of different prices, designs and of different ages, after the first 2000 miles of service, all seem to have about the same drawbar pull per ton weight, either coasting with a free clutch, or with clutch in, spark off and throttle wide open. This would indicate that the friction and road losses of present day cars in use do not vary greatly: this statement does not apply to Fords.

I do note a considerable variation in the rate of deceleration with clutch in, spark off and throttle open to the position required to drive the car at 20 miles per hr. on a smooth road. By the use of a large gear reduction, such as is common practice at the present time at speeds of average driving, there is a high vacuum in the intake manifold and in the cylinder during the intake stroke. This vacuum is about 7½ to 8 lb. per sq. in., and on the intake stroke gives rise to lost work. The mean effective pressure required to drive the car at average speeds on smooth roads must, therefore, be just that much higher. For instance, it is our observation that a 3¼ to 1 gear ratio will give a noticeably lower fuel consumption at ordinary conditions of steady driving than a 4¼ to 1 gear ratio. As an instance of this, we have found that to pull a certain 3½ by 5-in. six-cylinder car of 4000 lb. total weight at 20 miles per hr., which is 910 r.p.m. of its engine on high gear, requires 4.2 hp. or 12.6 lb. per sq. in. mean effective pressure with the clutch in and the throttle at the position corresponding to a speed of 20 miles per hr. on a smooth road, and 2.75 hp. or 8.2 lb. per sq. in. with the clutch in and the throttle wide open. Note the percentage of loss!

High gear reductions are used today mainly to ensure flexibility in operation of the car at low speeds. One of the reasons why this low-gear ratio is necessary is that the torque of many of our engines today falls off badly below 600 and sometimes 1000 r.p.m. I am quite sure that if our engines were designed so that the torque carried down to lower speeds, the car would be found to operate as nicely with a considerably higher gear ratio, and the fuel economy would be considerably improved.

It is today common knowledge that the difficulties encountered with "carburetion" are almost entirely due to the fact that parts of our fuels will not and cannot take the vapor form in the intake manifold, and their carriage and distribution to the cylinders has to be accomplished by the friction of the air carrying along the liquid drops and a film of liquid over the manifold walls. The distribution of this liquid part of the fuel is erratic and uncertain, and it is common practice to adjust the carbureter so that enough fuel is fed to furnish a combustible mixture from the elements which do vaporize in the manifold. This results in an irregular excess feed of heavy elements into the cylinders, which gives a heavy carbon deposit, fouls spark-plugs, destroys the valve seats, and, escaping past the pistons, interferes with the lubrication of the engine.

I cannot see that the use of a non-adjustable carbureter would help this condition in any way. When the engine is cold, the driver must have a rich mixture or the engine will not run at all, and whether the adjustment is on the carbureter or on the dash the average driver will not change his adjustment to follow the temperature. This adjustment dare not be accomplished automatically because of the great variation in the volatility of the fuels which are sold in different parts of the country and even in the same town, for an automatic temperature regulation which would be right for a heavy fuel would make it almost impossible to operate the engine on a lighter one.

I, therefore, believe that for the next 5 yr. it would be of great value to have a standard lighter grade of fuel which could be used on engines with an unheated intake manifold, or in the winter time on manifolds that are water jacketed or receive small quantities of exhaust heat. Engines which have properly proportioned "hot spots" could use the heavier fuels, as could engines which, though not so well equipped, operate under heavy loads so that their working temperature is kept up to a point of efficient operation.

F. E. Watts:—The most important issue raised by Dr. Dickinson's interesting paper is the question of a joint policy as to fuel development and sale to be formulated by the automotive and oil industries. While it is probable that we can build satisfactory engines to use almost any fuel if we know far enough in advance what that fuel is going to be, we are at present working practically in the dark and guessing at the future. The spectacle of the great automotive industries drifting along without making any systematic effort to settle the fuel question, upon which their continued prosperity depends, is appalling. A joint committee should be appointed. A survey should be made of the world's fuel resources. A list of available fuels, their amounts and their properties, should be published 3 and preferably 5 yr. ahead of production. If this is done we can develop engines to use these fuels economically. All other phases

of the question become relatively unimportant details compared with this.

DR. DICKINSON:—The point which Mr. Mock makes regarding the effect of gear ratio on fuel economy is of particular interest. This suggestion indicates that the inherent advantages of lower friction losses due to smaller size in the later engine designs of small size and relatively high-gear ratio may be more than counterbalanced by the increased pumping losses attending the increase in gear ratio. This illustrates the importance of a *complete* analysis of each of the elements in power loss.

It is quite true that the best fuel adjustment cannot be obtained with a non-adjustable carbureter design under varying conditions of temperature, volatility and viscosity of fuel; nevertheless, from a practical point of view it is almost certain that the inherent difficulties in these directions could be overcome sufficiently to permit satisfactory carbureter performance under all reasonable conditions without adjustment other than for idling, and with a much lower fuel consumption than is now secured in practice. While this may not be true for all existing carbureter designs, I believe that only minor modifications would be required to accomplish the desired result with any of the successful models. For instance, some effective means of temporarily securing much more complete atomization without increasing the mixture ratio when warming up an engine would produce, with a relatively small loss in volumetric efficiency, the same result as is commony produced by excessively enriching the mixture.

Mr. Mock's suggestion that a special lighter grade of gasoline be supplied for use in less modern equipment would offer an ideal solution from the point of view of the designer and user of motor vehicles. There are, however, very serious objections to such a plan, among which are the fact that to market a given quantity of such special gasoline would reduce the total available supply, and the demand for the special gasoline, if available, even at a very much increased price would be very large because of the added comfort and convenience in its use. The net result would be a marked reduction in available fuel, unless there is a corresponding increase in the equipment which will use the heavier grades of fuel.

CURBING THE ZEPPELIN'S USEFULNESS

IT may sound incredible that airplanes should be flown from platforms not more than 30 or 40 ft. long, but the deck flying branch did it every day in the week. This branch, which up to the surrender of the Hun fleet remained a naval secret, was organized to combat Zeppelin scouts. Seaplanes are comparatively useless for fighting Zeppelins. They are too heavy to go to 20,000 ft., and Zeppelins patrolling at lower altitudes can spot a seaplane too far away to enable the seaplane to close them.

Seaplanes have brought down Zeppelins in this war, but only by navigating through the clouds so that their approach was invisible. By surprising a Zeppelin before it has time to jettison its ballast and flee to 20,000 ft. the Zeppelin can be brought down. This is at best a piece of luck on the seaplane's part. Once a seaplane has closed a Zeppelin the "bag ship" is helpless. Heavy as a seaplane is, it is able to fly circles around a "Zep."

This also holds true of a light land machine and a seaplane. The little Camel scouts, which the deck flying branch use, can fly circles around any seaplane. Obviously, the same advantages a Camel has over a seaplane it has in still greater measure over a Zeppelin. It has, too, the added advantage over a Zeppelin that it can go up to more than 20,000 ft.; so a Zeppelin cannot rise to immunity from a Camel.

The problem of using the Camel was one of launching aircraft from the decks of ships. Time was when this was an experimental stunt and a risky one at that. But more recently it was part of the regular routine of light cruisers and battle cruisers operating with the Grand Fleet.

To some extent the difficulty was overcome by the construction of a special airplane ship, one of the "hush ships" of the Grand Fleet. With its weird dazzle paint and its long, flat deck, this gigantic vessel looks like anything but a ship at sea. A large number of Camels could be launched from her deck with comparative ease and safety. Had another Jutland ever "come off" she would have played a large share in it.

On the battle cruisers and light cruisers, platforms not more than 30 or 40 ft. long were constructed with the gun turrets as their foundations, from which the Camels "took off." The machines used to be perched like butterflies on turrets.

The landing is equally difficult and dangerous. Only the scout pilot can realize the difficulty of coming down on a ship's deck at sea. It had to be done, for the alternative was coming down in the sea, and dropping a land machine on the sea is one of the fanciest methods of suicide open to the service.

The use of the Camels against Zeppelins has more than paid. It has reduced the Zeppelin to a military instrument of such uselessness that in the drawing up of the armistice terms no Zeppelin surrender was asked. No greater contempt could have been poured upon the Zeppelin service than the omission of any mention of it in the drawing up of the armistice terms.

Nor was the usefulness of the Camels confined to the Grand Fleet. It was the deck fliers who caught and strafed the Gotha bombers on their return from London in the days when London raids were tried. It was the deck fliers who escorted seaplanes on countless raids on the Bruges docks. It was the deck fliers who destroyed Zeppelin sheds at Tondern. The deck fliers were a terrible thorn in the side of Hun seaplanes.

An American pilot, after having been fired on by a British patrol fleet, saw to his dismay a Camel taking off from the deck of the patrol leader. He knew his heavy seaplane was utterly helpless before the attack of a nimble little Camel, and at once banked sharply to show the markings on his wings. He was flying at 50 ft., for seaplanes get more speed on fewer revolutions when they have no altitude to keep. The Camel made straight for him and took up a position on his tail. He flew on, expecting every instant to be shot down, but apparently the Camel had recognized him. The last he saw of the Camel was the splash it made coming down into the sea.—*New York Evening Sun.*

The Motor Transport Corps and the Automotive Industries

By Lieut.-Col. Edward Orton, Jr.[1] (*Member*)

Annual Meeting Address

IN the interesting paper which has just been read by Mr. Utz on "The Story of the United States Standard Truck" the development by the Army of a specially designed motor vehicle for military service has been set forth. He has paid due tribute to the great part in that remarkable achievement which was played by this Society and by its members as individuals. He has not overdrawn his statements as to the credit due. I desire now to express for the Motor Transport Corps an acknowledgment of the very great value which is placed on the contributions of this Society and the services of its members. I desire to felicitate the Society on having been able to contribute so directly and efficiently to the country's need at that critical hour, and I prophesy that as years go on you will look back with very great pride and satisfaction on that record.

Vitally important as the standardized Class B military truck is, it is only one of many factors which operated jointly to create a unified Motor Transport Corps and to give to that Corps an honorable, and, we believe, a permanent place in the structure of the United States Army. It would not be proper to take up the time of the Society in this unscheduled and informal address by any attempt to sketch out the other components of that story or to piece them together. This will be available in official publications before many months, and those who are interested may read it at their leisure. The essential fact that a single organization to handle the motor transportation for the Army has been evolved, and that it is going vigorously forward in its work is, after all, the one point which cannot help being of interest to the automotive industries, and therefore to this Society.

Since the Motor Transport Corps will naturally be the largest user of motor vehicles of any branch of the Government service, and will affect by its example directly or indirectly many of the other branches of the service, its plans and policies should be known to and if possible approved by the automotive industries.

Future Plans of the Motor Transport Corps

It is thought that much is to be gained by a frank discussion of these plans at this time. The fact that the industry is now in a state of transition from a pretty nearly 100 per cent war basis back to a 100 per cent peace basis, and is still somewhat under the influence of the modes of thinking engendered by the stern necessities of war production, makes it especially important that it take stock of itself and ascertain just how far these military ideas are going to be perpetuated, and what influence they will have in the near future on the production plans of private manufacturers, and on private buyers. The following statement of policy has been framed for the Motor Transport Corps as representing its view of what the best interests of both the Government and the industry require. It has not been drawn with a selfish eye to present advantage, nor to feed personal pride in war-time achievements, nor any other similar motives. It is founded on principles, so far as the military part of it is concerned, which are absolutely unalterable and fundamental for military success. In the part dealing with the industries it is founded upon principles which are believed to be both just and generous, and which should bring to the support of the Corps a very large majority of the people in the industries.

In the statement of the policies which follows it is pointed out that the clauses are written in the form of recommendations from the Chief of the Motor Transport Corps to the Chief of Staff of the Army. These recommendations were approved on Feb. 4, as per the notation at the end of the document, so that these statements now bear the stamp of authority.

MEMORANDUM FOR THE CHIEF OF STAFF

SUBJECT Policy of the Motor Transport Corps with reference to standardization of equipment.

It is believed that the present is an opportune time in which to set forth to the automotive industries and the public the principles of the standardization program upon which the Motor Transport Corps is operating, as laid down in General Order 75, (War Department 1918) and in the various approved decisions made by the Motor Transport Vehicle Board under Special Order No. 91, paragraph 30, (War Department 1918). The reasons for so doing are to allay the speculation and unrest now exhibited in these industries, as to the Government's intentions with regard to the continuation and extension of the policies it has adopted during the war, thus permitting these industries to lay their plans and get back into their accustomed channels speedily.

The following statement of principles is submitted as representing what the Motor Transport Corps is doing and desires to do. Authority to make public announcement through the proper channels is requested.

Policy on Standardization

Standardization of Chassis The Motor Transport Corps recommends equipping the Army with only standardized chassis, designed specifically for military service, and for limiting chassis models to the least possible number required by the services to be performed.

Body Designs The Motor Transport Corps recommends that all special bodies needed by the various services of the Army be designed in conference with Motor Transport Corps engineers, to apply to one or the other of the standardized chassis.

Engineering Division The Motor Transport Corps proposes to maintain its Engineering Division under able leadership, and to charge it with the duty of keeping the standardized military models abreast of the progress of the times. The facilities available in the Motor Transport shops will make this work possible at the minimum expense.

Policy on Relations with the Automotive Industries

The Motor Transport Corps recognizes that the needs of the military service differ in many respects from commercial service and that therefore no effort should be made to secure commercial adoption of the military designs, or to encourage builders to produce vehicles from these designs for other than military and Government uses.

[1] Chief, service branch, Motor Transport Corps, Washington.

The Motor Transport Corps recognizes that its designs having been produced with the assistance of the combined talent of the automotive industries of the United States, working most unselfishly in a time of great stress, are in a sense public property. It does not desire to prevent the public from profiting to the maximum degree by this work. Therefore, in event of any private builders requesting permission to build and market commercially one or more of the standard military vehicles or parts thereof, they will be permitted to do so, provided they will obligate themselves to follow the specifications of the Motor Transport Corps rigidly, as to design, dimensions, material and treatment, and permit the Government every facility from time to time to satisfy itself that this is being done. Builders who comply with these conditions will be permitted to use the Government name and model designation, and make use of that fact in their advertising. Unless the conditions of this paragraph are complied with rigidly, the Motor Transport Corps will resist the use of its names and models by commercial builders.

Commercial builders who desire to produce cheapened or commercialized imitations of the standardized military designs, by use of some of their features but not all of them are free to do so provided they do not seek to use the Government name or model designation or associate their product with the same in advertising or otherwise.

Policy on Disposition of Commercial Equipment

On July 2, 1918, an Act was passed as follows:

"The Secretary of War may at his discretion deliver and turn over to the Postmaster General from time to time, and without charge therefor, for use in the postal service, such airplanes and automobiles, or parts therefor, as may prove to be, or as shall become, unsuitable for the purposes of the War Department, but suitable for the use of the postal service; and the Postmaster General is hereby authorized to use the same, in his discretion, in the transportation of the mails, and to pay the necessary expenses thereof, out of the appropriation for inland transportation, by steamboat, or other power boat, or by airplane, or star route."

Under the above, non-standard commercial vehicles, both new and those in use in camps, are being turned over to the Post Office Department, to meet its needs as nearly as possible.

After the above has been accomplished, such non-standard types of vehicles as are in camps, cantonments and posts will be withdrawn, where necessary, being replaced with standard vehicles and turned over for sale.

Unserviceable vehicles of non-standard types will immediately be available for sale.

After the requirements for the Army, constituted as in the bill submitted to Congress, have been met, and the objects laid down in the last three above paragraphs, have been accomplished, there will be no surplus motor vehicles for sale.

C. B. DRAKE,
Brigadier-Gen., U. S. A.
Chief, Motor Transport Corps

R. C. D. Operation Feb. 1, 1919
Feb. 4, 1919

Approved, with the understanding that the sales proposed in the second and third paragraphs last above will be made gradually and in such manner as not to disrupt the market for serviceable motor vehicles.

By order of the Secretary of War

HENRY JERVEY,
Major-Gen., U. S. A.
Assistant Chief of Staff,
Director of Operations

Only Standardized Chassis to Be Used

The following comments may be made upon this document, taking it up by clauses. It should be pointed out that the Army is firmly settled on using only standardized chassis hereafter, and that these standardized chassis shall be especially designed for military needs. Mr. Utz's paper contains a statement as to what, in general, constitutes the difference between military and commercial vehicles, and in addition to what he mentions there are a good many other things added to a military truck which commercial vehicles usually do not have; for instance, heavy front and rear bumpers, towing hooks, special lighting facilities, etc. The word *standardized* is used advisedly. It means absolute interchangeability throughout the entire structure. In the beginning of the work on the Class B truck this idea was derided by many manufacturers as something impossible of attainment, and even if attainable the cost would far outweigh the advantages; but the experiment has demonstrated that it is both possible and highly practicable, and something which should on no account be given up in future work. Attention is also called to the fact that this clause limits the number of models most severely, the present plan being for two passenger cars, four truck models and one motorcycle, or altogether seven vehicles which require engines. In addition there are some five or six trailer chassis and one bicycle, completing the list of fourteen. The present war has witnessed the purchase of at least 214 different makes of motor vehicle, many of which are represented by four, five or six models, so that there cannot be less than 600 separate models for which to maintain repair parts. On the basis of there being at least 1000 individual parts per model which will not fit any other vehicle, the magnitude of the spare parts program necessary to keep the trucks in operation is instantly perceived. The Army can see no possible way to accomplish its task unless it builds solidly on standardization and interchangeability to the highest attainable degree.

With regard to body design, it is pointed out that the number of vehicles now used in the Army is about 103, and that a good many of these vehicles represent modifications which did not really require special bodies. There was considerable lack of clear thinking in the early stages of the war, and the matter of bodies and the equipment carried in the bodies was often more or less confused, so that trucks were produced which were needlessly specialized. There is no disposition on the part of the Motor Transport Corps to deny the production of a special body for any purpose that really needs it, but where a special body is designed for any purpose, whether it be for a dental operating room, a loft for carrying pigeons, or a degassing truck for rescuing gassed victims, it is clearly evident that the design should be carefully correlated with the chassis which is to carry it, so as to secure proper load distribution, proper height above the roadbed, and other things. Cooperation between the Motor Transport Corps and the other corps of the Army will certainly enable considerable reduction in the number of types of body now on the list to be furnished.

The clause relating to the Engineering Division simply emphasizes that the Motor Transport Corps well understands the necessity of keeping its truck models abreast of the times. It recognizes that improvements are certain, and that no matter how good a vehicle is it will not remain good compared with the current products of the day unless advantage is taken of new discoveries and improved designs as they come. For the execution of this policy the Motor Transport Corps is now well fixed in view of the fact that it has three magnificent base shops, equipped with the newest types of machinery, where it can build and develop all the time at minimum

expense, and without infringing on the convenience of industrial concerns. It would even be possible to build secret models if there were any need for this being done.

Policy Regarding Building of Trucks

It is recognized that the military truck differs fundamentally from the commercial vehicle in the fact that it is not built in competition, and does not have to meet a price standard. It can be built with an eye to efficiency, dependability under military conditions of use, or to low maintenance cost. Commercial trucks must always consider the first, or sale cost, as a very vital fact in reaching their market, while the Army is able to consider the production from quite a different angle. That being the case, it is not the policy of the Army to encourage the trade to build or the public to buy military vehicles. The Army does not try to sell its particular brand of rifles to the public, but allows manufacturers of firearms to supply the public need. The Army does not try to impose its particular type of saddle or its particular type of harness or its specification for woolen blankets on the public. There is no greater reason why it should try to force its particular type of motor truck into public use. The public demands, and very properly, a cheaper and less durable grade of equipment than a soldier needs, because in private use better care can be given to equipment, which means longer life. But experience has shown that if the Army buys and uses equipment of ordinary and commercial grade it will not stand the service. For that reason Army specifications have historically always been drawn with severity, demanding high quality and unusual solidity and massiveness of design.

It is recognized that the design of the Class B truck was in a sense a great public effort. Too high tribute cannot be paid to the spirit of the men who made it. The public money paid for it. Therefore, if the public now want to use either the design as a whole, or the design of the parts and units, it ought to have that right, and will have it so far as the Motor Transport Corps is concerned. This privilege, however, does not imply the right to pirate or pillage the prestige which attaches to this great public effort. The Motor Transport Corps believes that private builders should do one of two things. First, either build the Government design exact and complete, and get credit for it; or second, build any improvement or modification of the design that they may think best, and then assume the responsibility for it. For instance, the Army does not want a "*near* Class B" truck or a "*near* Class B" engine. It wants a standardized Class B, or insists that that name be entirely avoided.

The Motor Transport Corps thinks that this is the only straight, open, honest course to pursue. It believes that the Class B truck is the best truck ever built, and considers it one of the real achievements of the war. It is willing to have its good points used freely by the trade to any extent wanted, provided the trade will cooperate to preserve the name and identity of the vehicle and to preserve that absolute standardization and interchangeability which are its chief assets. Obviously, this could not be done if different builders were allowed to make alterations and modifications as they please.

Disposal of Surplus Trucks

With reference to the policy in regard to the disposition of commercial vehicles now owned by the Army it should be stated that it has been recommended that no vehicles be returned from France excepting standardized vehicles and special equipment which would have no sale value in France, such as machine-shop trucks and other technical units. This restricts the question of the disposition of equipment, therefore, to that which is already in this country.

The connection which is established between the Post Office Department and the Army is a very important one, not only enabling the Army to get rid of its unstandardized equipment without loss to the public, but enabling the motorization of the Post Office, with all the attendant benefits, without causing new expenditures of public money. An additional advantage of this idea lies in the fact that in peace times the Post Office will probably be a very large user of motor trucks (perhaps even greater than the Motor Transport Corps), and by establishing this liaison the Army can be sure that there will be factories tooled up for the production of Army trucks, which would be a proved source of supply available for emergencies. Thus it is hoped to avoid a costly repetition of the experience just closing. By keeping the standardized vehicle hereafter in constant use by the Post Office the Army will be sure of the possibility of speedy production in the event of war.

With reference to the sale of vehicles of non-standard type, or unserviceable vehicles, the final clause in the document clearly shows that the War Department gives due consideration to the ill effects which would result from flooding the market with vehicles at this particular juncture. Anxiety on the part of the public with relation to breaking the automobile market is not warranted. The requirements for the Army have been calculated for an army of 500,000 men, and these calculations show but a small excess stock of some types of vehicles and considerable deficiencies in other types. The grand total will be a surplusage of only 4 or 5 per cent. The needs of the Post Office Department are expected to absorb this quantity at once, especially since the surplusage happens to be in the types most useful for its work.

Should a change of policy occur, due to Congress adopting plans for an Army of a different size or a composition different from that now under discussion, there is a possibility, of course, that there would be a lot of equipment declared surplus. The danger from such a move will be minimized the longer it is deferred. Just now, with the industries beginning to start on a peace basis, would be the worst possible time in which to market a large supply of used equipment and vehicles. It is not believed, however, that there is ground for anxiety on this score.

In conclusion, the Motor Transport Corps believes that in giving this platform to the automotive industries of the country it is doing the utmost possible to continue and still further strengthen the relations of good will and mutual advantage which have thus far obtained. It believes that the policies here set forth are good for the Army and good for the industries. It believes that no one will dispute the Army's right to the complete standardization of its equipment and the simplification of its program to the greatest possible degree in the interest of economy and efficiency, both in peace and war. Nor is it believed that any other policy than making freely available to the general public the fruits of the tremendous work and large expense which have been lavished on truck production during the war should be considered. In this way some portion will come back to the people in the form of better trucks for all.

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A Comparison of Airplane and Automobile Engines

By Howard C. Marmon[1] (*Member*)

Annual Meeting Paper

In physical construction the four-stroke cycle airplane and the automobile engine are identical. From the delivery of the fuel to the carbureter to the delivery of the power generated at the crankshaft end, the processes are the same. An automobile engine could be made to fly an airplane, and an airplane engine or a replica of it on a reduced scale to bring the power within usable limits, could be employed to operate an automobile. A long series of disappointments has emphasized to all of us the fact that any aggregation of parts assembled to obtain a mechanical result is a series of compromises, and the relative importance of the objectives governs the nature of the compromise.

Controlling Factors in Design

The major objectives that govern the compromises to be made in the design of airplane or automobile engines are roughly as follows in approximate relative importance. We are considering the airplane engines that have been developed for use in warfare. They must have

(1) Reliability
(2) Small weight per horsepower
(3) Economy in fuel and oil consumption
(4) Carburetion that permits easy starting and maximum power through a range of 30 per cent of the speed range, and idling at one-quarter maximum speed without danger of stalling. In short—no great degree of flexibility is required
(5) Ability to deliver full power through a small speed range without excessive vibration
(6) Complete local cylinder cooling under conditions of high mean effective pressure
(7) Compactness

In general, it can be assumed that the airplane engine will receive expert attention daily; it will be operated on a homogenous highly volatile fuel and be lubricated with good oils. Relatively little regard need be given to the expense involved in fabricating any part of the engine or in the original tooling-up. Further, a comparatively small part of its life will be spent at sea level and none in a dust-laden atmosphere.

The automobile engine must have

(1) Reliability
(2) Silence
(3) Carburetion that accomplishes proper and even firing in all cylinders under varying throttle conditions, through speeds covering more than 90 per of the speed range of the engine. In short—great flexibility. Economy is secondary to this requirement
(4) Ability to deliver partial or full torque through its entire range of speed without vibration
(5) Compactness
(6) Small weight per horsepower

In general, it can be assumed that the automobile engine will receive attention at infrequent intervals and then usually at the hands of an inexpert person. It will be operated on fuels of low volatility and lacking in uniformity, and varying grades of lubricating oils will be used. The cost of fabricating the parts and tooling-up must be kept in mind. Further, the engine must be designed to operate at higher speeds than is customary in airplane engines. Its entire operation is likely to be near sea level and often in a dust-laden atmosphere.

Reliability has been given as a prime requisite for both types of engine. It should be remembered that an automobile which has traveled 10,000 miles has had its engine running from 300 to 500 hr. This is considerably in excess of the normal life of an airplane engine in warfare. A typical two-seated airplane loaded with all its paraphernalia for reconnaissance work and the incidental fighting would, as it left the ground, have 20 per cent of its weight represented by bare engine and 15 per cent by fuel for a 3 or 4 hr. flight. These figures represent the extreme that has been attained in lowering the power-weight ratio and in fuel economy. A typical automobile carrying five passengers and fuel for an 8 or 10 hr. run would have, not including flywheel, clutch and starter, less than 10 per cent of its weight in engine and 3 per cent in fuel.

In obtaining the greatest power output per pound of weight, it is necessary to get the greatest power output per cubic inch of piston displacement. In the airplane engine the most successful solution has resulted from the use of a compact combustion chamber, valves of ample size, large passages in the intake manifolds, carbureters designed especially for the engine speeds contemplated, and the highest practical compression pressures, bearing in mind that a fuel of high volatility is to be used and much of the operation is to be at reduced barometric pressures.

The automobile engine will not equal the airplane engine in power per cubic inch piston displacement, as it must be carbureted for greater flexibility and not solely for maximum torque output through a comparatively limited range of speed. Two to four carbureters, as is usual on multi-cylinder airplane engines and which add to their maximum output, would not be welcomed on the automobile.

Nor can the automobile engine use a compression pressure as high as that of the airplane engine, which means that its power for a given displacement, output and fuel economy must be lower. The high compression pressures would be impracticable at the full load and low engine speeds required of the automobile engine, but not of the airplane engine.

The lower grade fuels commonly used in automobile engines are more troublesome under high compressions than the fuels customarily used in airplanes. It should also be remembered that the higher the compression ratio it is possible to use at ground level in an airplane the better the engine functions at altitude. At an elevation of about 15,000 ft. the compression pressure is reduced about 40 per cent.

[1]Vice-president, Nordyke & Marmon Co., Indianapolis, Ind.

Compact combustion chambers make valves in the head necessary. Mechanically the most efficient way yet devised to actuate these valves is the overhead camshaft and the use of abrupt cams. The gear train for operating the overhead camshaft from the crankshaft is rather complex and expensive, but by using proper materials can be made very light and durable.

Reduced Weight in Cylinder Construction

The greatest weight reduction in cylinder construction seems to be obtained in the steel cylinders with welded-on jackets, usually individual. All-steel cylinders are available only for valve-in-the-head engines. Steel cylinders have a particular advantage in that it is possible to get cooling water close to the interior walls of the combustion chamber and to the valve seats. This is of considerable help in connection with high mean effective pressures and tends to reduce carbonization. Steel cylinder walls can be made so thin that they will permit the bore of the cylinder to increase 0.010 to 0.012 in. during the explosion stroke without affecting the power output.

If the steel cylinder is the lightest and lends itself readily to the most effective way of producing power for a given displacement, why should it not be adopted for automobile use? For passenger car use its comparatively excessive cost is the least of the objections. *Per se*, the steel cylinder wall offers no advantages over cast iron. In European aviation practice, notably in air-cooled engines, steel cylinders have been lined with cast-iron sleeves about 1/32 in. thick. In its best development, for ease of manufacture, least amount of water weight, and the best circulating water distribution, the steel cylinder is of the individual type. Individual cylinders in a passenger automobile are not desirable because of the increased over-all length consequent upon such a design, the multiplicity of water, gas and exhaust connections and valves in the head. With steel cylinders valves in the head may be operated by push-rods from a camshaft in the crankcase, as in the Benz aviation engine, but for automobiles the problems of enclosure against dust and proper lubrication of parts present difficulties that are not easily solved.

An attempt to operate the valves of a passenger automobile with the overhead camshaft would not be likely to succeed commercially. Not only would its comparative complexity over other methods of valve operation producing excellent results be against it, but, what is more important, no durable way of driving an overhead camshaft and all the accessories required on an automobile has yet been devised. It seems to be fundamental that a passenger car engine must operate with a total amount of noise that is, at the most, unobtrusive.

In addition to this, the cylinder walls would have to be thickened to a point where no spring from the explosion pressures would result in that constant source of trouble to the manufacturer, piston slaps. Some of the weight advantages would diminish with this change.

One of the greatest contributions to our knowledge of engine manufacture resulting from airplane engine production is the steel cylinder, and, strangely enough, probably the greatest application of steel cylinders will be on the large truck or the tractor engine. Here the noise is less important, as is also the fore-and-aft bulk. The unusual cooling advantages offered by the steel cylinder fit it particularly for heavy duty under the unfavorable conditions often required of the truck or tractor. The small relative mass of such cylinders is conducive to their staying in place without the loosening or fracture due to the excessive vibrations often encountered in such cases from causes other than engine operation.

Design of Crankshafts and Crankcases

In the design of an airplane engine crankshaft, the need of minimum weight per horsepower will govern. A material of high specific strength will be used, and empirical data will be employed in the design to avoid periodic vibrations in the narrow speed zones in which the engine operates. In the layout of the automobile crankshaft, it must be remembered that all periodic vibrations must be avoided from the lowest speed to speeds higher than those employed in the airplane engine. This results in designing for a certain stiffness, which would enable the use of material relatively inferior but still having sufficient strength. Hence the requirement of smooth operation under a greater variety of conditions makes it impossible to meet, in the automobile engine, the low weight factors of the airplane engine.

What may be termed the "tubular" type of crankcase is the lightest on a power-weight basis and presents the greatest opportunity for heat dispersion from bearings of any crankcase design yet offered, and is widely used in airplane engines. It is split on its horizontal axis, the upper portion carries one-half the crankshaft bearings and the lower portion the other half, and the two halves are bolted together with bolts going entirely through the case. The conventional automobile design, in which the upper half of the crankcase, plus whatever bridgework reinforcement the cylinders offer, carries the entire crankshaft load, the lower half being merely an oil container, is quite appreciably heavier. It will, however, in all probability be retained for automobile work on account of its greater accessibility and the greater ease with which corrections for wear can be made.

Total bearing loads and the effect of parts that apply these bearing loads will be greater in automobile than in airplane engines, as higher engine speeds must be provided for. The forces due to reciprocation of parts become greater in proportion to the horsepower output than in the airplane engine. The factor V^2 of the MV^2 equation increases more rapidly than the factor M can be reduced.

Higher mechanical efficiencies with their correspondingly greater horsepower output per cubic inch will be obtained from the airplane engine than from the automobile engine. The easy clearances on the pistons, the ample freedom given all the bearings, the gear trains, etc., that mark the assembly of the airplane engine produce a machine that responds and is ready for the hardest duty at the moment it is first "fired." Give the automobile engine this same mechanical freedom, and one of the prime requirements of automobile engines—silence—will be so lacking that the engine would be promptly condemned.

The need for economy of fuel and oil has been emphasized. It appears that any fairly conventional water-cooled engine with a reasonably compact combustion chamber with cylinders sufficiently well cooled locally to permit good compression pressures, can reach ½ lb. of fuel per b.hp.-hr. over the speed and power ranges required. Over equivalent ranges, with proper allowances made for reduced compression ratios, automobile engines will compare very favorably. However, the requirements of great flexibility, sudden demands for idling, quick acceleration in crowded traffic conditions, present economy

problems for which airplane engine history provides no parallel.

While the steel-cylindered airplane engine has been considered principally, it is not intended that the well-known aluminum jacket engines, and the Bugatti extraordinarily clever design using all cast iron above the crankcase, which engines produce much the same results when installed in an airplane, be overlooked. They have one advantage for automobile use not possessed by the steel-cylinder engine—more complete enclosure of valve operating parts. However, an analysis of all of them will show that the objectives aimed at have necessitated compromises as do other constructions.

An Airplane Engine in an Automobile

Let us now see what happens if we take any four, six, eight or twelve cylinder aviation engine and make a faithful replica of it on a reduced scale so that its power output fits the needs of the particular car we wish to try it in. The engine will be heavier per horsepower than its prototype; cylinder walls will be as thick; crankcase walls will be as thick, as undoubtedly foundry practice dictated the thickness of the larger one; ignition, spark-plugs, float chamber and many similar parts will weigh as much per cylinder as in the larger engine. The weights in pounds per horsepower will show a considerable increase. However, when installed in the car, and the usual flywheel, clutch, starting and lighting systems, tire pump and so on are added, it will weigh from one-half to two-thirds as much as engines employed in our usual practice.

A trial of the car so equipped will show some extraordinary performances in speed and hill climbing when the original start for the hill is rapid. City driving under traffic conditions or heavy pulling at low speeds will demand a new carbureter and intake system to meet these conditions. This will seriously affect the conditions that made the first impressive performance. When satisfactory control of the engine has been established, noises demand attention. A general snugging up of parts helps, but a few noises remain that it is finally decided can be corrected only by a redesign, probably of the valve operating gear. All this affects the original performance adversely. After this has been done, certain conditions of operation will require an enlargement and stiffening of the crankshaft to eliminate an annoying periodic vibration. The result is an engine not a great deal lighter or more efficient than the one originally designed for the car.

The airplane engine is a more expertly engineered and better manufactured development of the internal-combustion engine than the automobile engine. It is, however, developed for a set of objectives different from those demanded in an automobile, and none of its major features can be directly grafted upon the motorcar. It is true that a multitude of engineering minutiae have been developed that are applicable to the motorcar, but the total result in operating performance is small.

The greatest contribution from the airplane engine to the motorcar industry has come through the builder of the engines. He has shown that, given a definite set of specifications and a definite request for results, engines will leave his factory with absolute assurance as to what they can do. Some of the optimists have suspected this, but the war's aviation engine experience has proved it.

Motorcars will be improved as a result of our airplane experience, but this improvement will be apparent in the service the car gives, rather than in any radical changes in design. This will come about as a result of better manufacturing facilities, higher shop standards and more intelligent inspection.

LESSONS OF WAR COST-FINDING

BEFORE this country entered the war and, therefore, before war powers could be exercised in control, a huge and false price structure was built up and in spite of all that could be done became more aggravated. Cost of living and wages went upward as prices rocketed. That price structure and its attendant inflations today, are among the chief perils of the reconstruction period. That they are no greater can be attributed almost wholly to the cooperation of industry in the program of price-fixing which checked, so far as possible, mounting prices and, for the time, negatived price based solely on supply and demand.

One great handicap lay in the fact that basic natural resources had been appreciated in value before the price-fixing function came into operation. European belligerents had for three years been bidding, frantically, the treasures that nature had placed under our stewardship and as a result our raw materials had been hugely written up before the United States entered the war. So when price-fixing was undertaken it started from inflated value for undug ores and coal, untouched petroleum and uncut forests. Despite this false start and the difficulties that flowed therefrom, cumulating in all subsequent industrial operations, price-fixing did stabilize industry and insured it against ruinous collapse at the end of the war.

It is estimated that, in its work for various Government agencies, the Federal Trade Commission obtained cost and production figures of upward of 10,000 companies in scores of important industries and many minor ones, which had an approximate aggregate investment of $20,000,000,000 and the commodities directly affected by the such cost-findings represented annual sales values of at least $30,000,000,000 not far from twice the amount of the First, Second and Fourth Liberty Loans taken together. These cost studies demonstrated frequent and great deficiencies in the accounting methods employed by mining and manufacturing concerns and especially in cost-accounting methods. In some of the oldest and greatest industries there was not even an attempt at that determination of unit costs and profits by products which is essential, generally, to the safe conduct of industry.

It is evident that where such cost accounting is not established it should be introduced and where it is defective it should be reformed. Inventories should be carefully kept; labor and material used should be accounted for as used; indirect and overhead charges should be fairly allocated and proper allowance made for depletion and depreciation of resource and plants. On the other hand, capital charges for construction should not be mingled with operating or production expense nor should there be introduced items of actual or imputed outgo such as income and profit taxes, depletion of appreciation of plant investments, or interest on capital owned. However, where complete records are kept, it is relatively easy to correct bad principles, reject improper items or introduce omitted ones. Inventories and records of expense and sales by products are necessary to compute profit and loss by products.—William D. Colver.

Possible Effect of Aircraft Engine Development on Automobile Practice

By Henry M. Crane[1] (*Member*) Annual Meeting Paper

DURING the four and one-half years of the great war, an enormous amount of development work has been done on various types of engines suitable for use in aircraft. Many of the ablest engineers have given their whole time to this work, while practically every engineer with any knowledge of internal-combustion engines has given the various problems involved more or less thought. It is only natural, now that peace has come, to speculate as to what effect the knowledge thus gained will have on the design of motor cars. Possibly if we will consider the various engines of different types that have proved themselves in the war, it will help us in arriving at a conclusion.

These engines may be classed roughly as follows:

Radial air-cooled with rotating cylinders, such as the Gnome, Le Rhone, Clerget and Oberursel.

Radial air-cooled with fixed cylinders, such as the Anzani and A. B. C.

Radial water-cooled with fixed cylinders, such as the Salsom.

Six-cylinder vertical water-cooled, such as the Mercedes, Benz, Austrian Daimler, Maybach, S. P. A., Fiat, Isotta Fraschini, Lorraine Dietrich, Liberty and B. H. P.

Eight-cylinder V-type, water-cooled, such as the Hispano-Suiza, Liberty and Sunbeam.

Eight-cylinder V-type, air-cooled, such as the Renault.

Twelve-cylinder V-type, such as the Liberty, Rolls-Royce, Fiat, Renault and Lorraine Dietrich.

The V-Type Engines

The V-type engines mentioned above are those comprising two rows of cylinders. There have been a number built, also, with more than two rows of cylinders, but none of them has come into any considerable use, and in any case it is difficult to see how they would have any bearing on motor car practice. There have also been several engines having eight cylinders in a row, such as the Mercedes and Bugatti, but these do not seem to be interesting to the motor car engineers.

If we look at aviation engine design, as represented above, from a general point of view, there are several interesting features of considerable prominence that are practically standard at the present time. These features are the four-stroke cycle, the use of valves in the cylinder-heads and the use of more or less complete force-feed oiling. I do not want to be understood as saying that engines not embodying these features have no great possibilities. I have limited myself in this case to the engines that have actually proved themselves in service.

I think it is fairly obvious why the apparent standardization has taken place on the lines described. There is no question that the four-stroke cycle poppet valve engine, with valves in the head, is the lightest for its horsepower that has yet been developed into commercial use. The valve-in-the-head type, using poppet valves, has the simplicity, compactness and light weight of individual parts, which make up a light total weight. The four-stroke cycle, due to positive charging and efficient scavenging, allows very high speeds, and therefore high powers for a given size cylinder, as well as excellent fuel economy. The constantly increasing speed of airplanes and the development of geared engines have made it possible to take full advantage of these characteristics.

The use of force-feed oiling has naturally come to the front, in view of its positive action, and because the oil circulation is of great assistance in cooling parts of the engine that would not otherwise be properly cooled.

Of course, we know that the important feature in an airplane engine is reliability of operation, together with the lightest possible weight for a given power, the weight necessarily being taken as that of the whole powerplant, including all cooling accessories, fuel, oil and the necessary tanks for the length of flight required. On the other hand, long life, durability and ease of repair, while they have received a great deal of consideration, have naturally been of considerably less importance than usual, because of military considerations. Aerial warfare is more or less an informal racing proposition without any particular rules, and with the life of the pilot frequently paying for defeat. The question of first cost and the cost of maintenance, therefore, cannot be given the same consideration as in the more commercial motor car field.

It is the striving for light weight and compactness that has resulted in the various radial engines, as well as the V-type engines. It has also resulted in the development of improved forms of cylinder construction, this being a point where the greatest weight saving could be made, cast-iron cylinders due to the inherent weakness of material and methods of fabrication being extremely heavy in proportion to the work performed. The steel cylinder has become almost universal in military engines for these reasons, being formed with radiating fins in air-cooled engines and provided with suitable water-jackets in water-cooled engines.

Water-Cooled Engines

In the water-cooled engines, two pretty definite types of construction have come to the front. The Mercedes type, in which a complete cylinder unit, including the water-jackets, valve-ports and other fittings, is made up of various parts, all of steel, in most readily machinable forms, these parts being welded together. A very large number of successful engines, including our own Liberty engine, have been constructed in this way. The second system first came into large and successful use in the Hispano-Suiza engines. In this system, the cylinder wearing surfaces are of steel, while the water-jackets, valve-ports and other parts are cast aluminum. A number of interesting modifications of the Hispano-Suiza de-

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sign have recently been proposed and some of them undoubtedly will prove to be successful.

It might at this point be interesting to the members to hear that we have recently completed an engine similar to the 300-hp. Hispano-Suiza, the only difference being in the use of a steel cylinder construction, and that the weight of the two engines proved to be almost identical, the one with steel cylinders being slightly heavier dry than the one using the aluminum casting construction, but the weight with the jackets filled with water is almost identical because of the smaller amount of water carried in the steel-cylinder unit.

There has been a steadily increasing use of aluminum-alloy pistons in aviation service, partly due to the light weight, but more because of the very much improved cooling due to the high heat conductivity of this material.

Of course, crankshafts, crankcases, bearings, etc., are considerably lighter for the horsepower developed in aviation engines than in pre-war automobile designs. We must remember, however, that aircraft engines are not subjected to external shocks and vibrations to anything like the extent that automobile engines are, and, furthermore, that quietness of operation can be absolutely disregarded. If we add to these facts the point already stated, that durability, ease of manufacture and of repair have been sacrificed to a considerable extent to the saving of weight, we can reach a more just estimate as to the possible value of such improvements in future automobile designs.

A contributing factor to the lowering of the power-weight ratio has been the ability reached to maintain very high mean effective pressure in large-size cylinders. A number of very light engines are successfully developing 45 hp. per cylinder and are able to maintain this power for hours at a time. Mean effective pressures as high as 130 lb. are being maintained on cylinders having piston displacements of 140 cu. in., with compression ratios of 5.35 to 1.

There are two other things which have assisted in lightening engines, these being greatly increased power, which means that planes no longer need to be operated continuously with wide-open throttle, and that much of the flying is being done at considerable altitudes. This latter feature has a very marked effect on the reliability and life of all aircraft engines. Various schemes have been tried out with the view of obviating the loss of power with altitude in aircraft engines, but naturally such devices have no practical bearing on automobile work.

Another line of development which has a very direct bearing on automobile engine design was just coming to the front at the end of the war. This is the production of composite fuels. The admixture of one part benzol with four of gasoline raises the ignition temperature of the mixture to practically that of benzol. This allows of increasing compression ratios far beyond anything that is feasible with gasoline alone. While this is of undoubted value in connection with the very high-grade gasoline used for military aviation, it has a far greater interest in connection with the very much less volatile gasoline used daily in automobiles. The temperature at which gasoline ignites becomes lower and lower as less and less volatile grades are used. While we can look forward very hopefully to the effect of this new fuel development in automobile work, we must not forget that it does not solve the questions of vaporization and distribution, which are always present in using gasoline having a high boiling point.

Use of Improved Materials

Regarding the question of materials, the recent advance in aircraft engines can, I think, be attributed almost entirely to a more general knowledge of materials already in use before the war. Very much higher grade aluminum castings are required than were commercially possible several years ago. Improvement came rapidly with the increasing Government demands, but it was due to greater care and better methods rather than to any new inventions.

The same situation holds good with regard to the various steels required. In the Hispano-Suiza engine we are using exactly the same steels we have used in motor cars for the last 10 yr., with the exception of exhaust-valve material. The use of steel having a chromium content of 12 per cent, the so-called "stainless" steel has, because of its non-oxidizing properties at high temperatures, been very satisfactory in exhaust valves. The Liberty engine also requires no fancy materials for its successful operation. The main thing is that information regarding the manufacture, heat-treating and testing of alloy steels is much more widely distributed than before. Personally I have learned that the fabrication of the steel to be employed is far more important than the analysis. For example, a carelessly manufactured chrome-nickel steel is a snare and a delusion. I have often felt like building one Hispano-Suiza engine using nothing but straight carbon steel throughout, provided I could get such steel fabricated with the care used in making alloy steels. I have very little doubt that such an engine would stand up in direct comparison with our regular product.

There is another point of vital importance in aircraft engines, and that is the main and connecting-rod bearings, especially the latter. I think that we have learned a great deal about making babbitt-lined bearings with bronze or steel backs since the war started, but we have been able to get excellent results with the same grades of babbitt and bronze as were used before the war, improvements being made in the method of fabrication. We have run our 300-hp. engine for hours at a time, taking from 75 to 85 hp. out of it per crankpin. Each of these bearings is about 2½ in. long, disregarding fillets, and 2⅛ in. in diameter. These engines, when run at sea level, preignite practically all the time, the best power being obtained in this manner.

We have come to the use of a rather heavy bronze back babbitt-lined bearing for this work, with sufficient oil circulation not only for lubrication but for cooling also. The smaller Hispano-Suiza engine, as well as all the engines that I have ever designed, had very energetic circulation, being far beyond immediate lubrication requirements. When the 300-hp. type was being developed the oil consumption ran very high in the early samples, and there was a suggestion from the other side to remedy this by reducing the oil flow through the crankshaft. We believed this to be a mistake, and that no such action would be necessary with proper cylinder and piston design, and this proved to be the case. With the best that we can do, in lubrication and cooling, however, unless there is a 100 per cent bond between babbitt and bronze, the bearings will not stand up, the babbitt cracking and flaking off after longer or shorter periods of operation. From our own experience we have concluded that all efforts to hold the babbitt mechanically, as by the use of holes, dovetails or screw threads, for example, accomplish no good purpose, the trouble with most of them being that they are more or less local, and also that they

make rapid variations from point to point in the cross-section of the babbitt. The screw-thread system possibly has not these defects, but it has two others; first—the difficulty of getting absolute cleanliness, and second—the probability of entraining air when pouring the babbitt. After all is said and done, the one sure method consists of absolute cleanliness. If the bronze is unoxidized and the tinning is maintained in an absolutely unoxidized condition until the babbitt is poured, nothing else is required to make a thoroughly satisfactory job.

Ignition

We must not overlook in this discussion the question of ignition. With detailed improvements in engine construction, higher and higher compressions have been successfully used and necessarily higher and higher explosion temperatures. In modern aviation engines, spark-plugs which will run successfully in automobiles for thousands of miles without attention fail in 5 min. of full-load operation. The spark-plug is a study in itself, being a beautiful compromise between running so cold that it will become fouled with oil and running so hot that it will cause preignition, or that its insulating properties will break down, causing delayed ignition or misfiring. Tremendous advances have been made in the quality of insulating material and in the detailed design of plugs, which will undoubtedly have a tendency to improve the product for automobile uses.

The effect of steady high-speed running with accompanying shocks and vibration on magnetos, especially of the eight and twelve cylinder types, has forced a very great improvement in detail manufacture in this line. It is unbelievable that it will not have its effect on subsequent commercial manufacture. I think this is equally true of the battery ignition systems, which have come into successful use on aircraft engines during the war.

Because of the very high operating pressures and temperatures, valve or piston leakage in aircraft engines becomes a most serious matter. No new inventions in piston rings have been required to meet this condition, but simply a higher grade of fabrication on already standard lines.

In the accessory field, the design of radiators has been given a new impetus. In many motor cars the radiator, due to different features of design, is larger than is absolutely necessary and the most efficient types of cores have not been required. I feel sure, however, that the new types developed for aircraft work, such as the single hexagon tube construction, will prove to be very useful in automobile work.

Radical Changes in Design Unlikely

Looking back over the facts brought to your attention in this paper, I feel certain you will agree with me that there is no reason to expect any radical change in automobile design, due to aircraft engine development. Nearly every feature of design that I have described has been used in motor cars. For instance, an eight-cylinder V-type engined car was actually produced by E. R. Hewitt in 1908, following the idea first put into service in the Antoinette aviation engine. I do expect to see an increase in the number of valve-in-the-head engines, due in part to the general efficiency of this arrangement, but more especially to the fact that this construction lends itself extremely well to the separable cylinder head, which is coming into continually greater and greater use. We have already seen a number of successful engines with cast-aluminum block-cylinder construction and this development may be expected to continue.

I have purposely based my consideration of this subject on the commercial use of motor cars for passenger and freight service. In racing cars, of course, the effect of aviation engine progress is bound to be extremely marked, as the service required is very similar in the two cases. In commercial motor car work, however, the percentage of the total loaded weight which can be saved by detail lightening of the engine is not very great, and this saving is apt, as I have pointed out, to be at the expense of durability and ease of construction and repair.

Furthermore, in my opinion the motor car engine should be designed to develop its best pulling characteristics at considerably lower speeds than does the aircraft engine, which will undoubtedly mean very much lower compression ratios and lower mean effective pressures.

To sum up, I think that we shall in the future have a continual and beneficial interchange of information and ideas between the two lines of engineering, but I think, also, that the lines of design will draw rather widely apart, due to the very different problems to be met in the two classes of service.

INDUSTRIAL BOARD TO STABILIZE PRICES

THE Industrial Board of the Department of Commerce has been created by Secretary Redfield and will be charged, under the approval already given by the President to the Secretary of Commerce, with the stabilization of prices for basic materials in such a fashion as to create a firm foundation on which the consumer can base his future purchases and the producer can form necessary production cost estimates. Its program will be supported by the Council of National Defense. This board consists of six men. The chairman is George N. Peek, formerly vice-chairman of the War Industries Board. Hugh Frayne, the labor representative on the board, was also on the War Industries Board as the representative of labor, while the official representative of the Government in the organization will be Thomas C. Powell, director of capital expenditures of the Railroad Administration.

Through proper investigation and stabilization it is expected that the foundation can be laid for the resumption of American business and for the furnishing of employment to returning soldiers and sailors; through Government purchases, the publication of fair price lists, and cooperation of the producer. To obtain cooperation of the producer, it is planned that the Board shall call the various leaders of industry into consultation. It will be the endeavor of the Board to interchange views with these representatives of industry in the fullest and freest manner possible. If these conferences result in a general agreement among the important basic industries upon proper prices and bases for prices at which sales will be made, and this agreement is approved by the Board, it is believed that the announcement of this fact will induce the nation to feel justified in properly beginning a buying program.

Probable Effect on Automobiles of Experience with War Airplanes

By O. E. Hunt[1] (*Member*)

Annual Meeting Paper

THERE seems to be an impression in some quarters that the aircraft experience of the last two years should have taught engineers how to revolutionize car construction and performance. The facts appear to offer no real foundation for such an opinion.

In general, cars and airplanes can be divided into the same design elements. They both have powerplants, systems for the transmission of power from the engine to the point of its absorption, running gear, bodies and controls. Let us take each of these elements and compare its design and the conditions surrounding its use in both types of service to determine if the development of the element in the one service will automatically tend to produce a similar development in the other.

Control and Body Differences

Controls in both cases have to cover the functions of steering and changing speed. In the case of the plane, the steering function is performed by ailerons, elevator and rudder, the first two controlled from the hand-operated stick and the last from the foot-operated rudder bar. Changing speed with relation to the ground is accomplished in the plane by changing the engine speed with the conventional spark and throttle controls, by changing the attitude of the plane in the air with the steering controls, and by taking advantage of wind currents. For instance, the reduction of speed accomplished in a car by throttling the engine, declutching and braking, would be produced in a plane by throttling the engine, increasing the angle of the planes to the direction of flight and heading into the wind. In landing, an incidental and added braking effect is obtained from the dragging tail skid. It is perfectly obvious that developments in airplane control are not going to revolutionize car control. The two systems are fundamentally different.

In the airplane, the body or fuselage performs many more functions than in a car. Aside from seating and protecting the passengers, it is the chief structural member of the machine and carries the engine, the supplies and the useful load, which functions are performed by the chassis in the case of the car. Maximum strength with minimum weight exercises a controlling influence in the design of a fuselage, with the result that the convenience and comfort of the passengers receive but scant attention. Doors and stepboards for convenient entrance would add weight, weaken the structure, and increase wind resistance. Consequently, the passengers reach their seats by scaling the side of the machine and sliding down through an opening in the top of the body. The seat, as a rule, is scantily padded, presumably to reduce weight. The leg room is usually scant. A view of the surroundings is insured by placing the seat so that the passenger's head sticks up through the opening by which he entered. The windshield function is supposedly performed by a small piece of glass or celluloid set on top of the fuselage, just forward of the cockpit; but in my experience, goggles are the real protection. It is hard to conceive that information which would help us to improve car bodies, where comfort and convenience of passengers are prime requisites, can result from a study of fuselage construction. Due to the radical differences in design, there is little, if any, structural detail that could possibly be used in car bodies. An increased use of stamped braces and the possible use on the more expensive bodies of bent structural parts of veneer, are the only immediate possibilities for body structure suggested by a fairly intimate knowledge of airplane body design.

In a car, the chassis is the backbone of the whole structure. In a plane, it is a parasite when the machine is in the air, and is so considered in connection with plane design. Being useful only in taking off and landing and a drag on performance due both to weight and wind resistance when the plane is in the air, its bulk and weight are made as small as possible; and since, in theory at least, taking off and landing are done on specially prepared fields, the factor of safety is made much less than in the corresponding element of the car. The chassis is fundamentally simple in construction, too, because its axle exercises neither a steering nor a torque transmitting function, as in car axles. The only possible contribution to car design that could result from experience with the airplane landing gear would be the development of light wheels and tires that might some day find a place on high-grade light cars.

An airplane is almost entirely devoid of a power transmission system. The conventional airplane engine has the propeller mounted directly on the end of the crankshaft. For certain purposes, reduction gears of a fixed ratio are used to drive from the crankshaft a layshaft carrying the propeller, but gear changes, such as are applied to cars, are unknown. The only element of the power transmission that has a counterpart in car work is the propeller-hub which performs a similar function and is similar in design to the rear wheel hub of cars. Airplane propeller-hubs must be readily demountable and this requirement has resulted in some new design detail that is entirely unnecessary for cars.

Airplane and Car Engine Service Conditions

But the engine, you say, is a different matter. Has not the war proved that highly developed, water-cooled, fixed-cylinder engines of the automobile type are the most dependable airplane engines at the present stage of the art; and will not the experience gained in reducing the weight and increasing the volumetric efficiency of these airplane engines be of immediate use in decreasing the weight-horsepower ratio for car engines? This may help in a limited way but not nearly to the extent some engineers would have us believe, because, in spite of similarities in design, the engine requirements for airplane service are so far different from those

[1]Chief engineer, carriage division, Packard Motor Car Co., Detroit, Mich.

for cars that factors which are vital in the former type of machine are of minor importance in the latter and vice versa. In an airplane engine dependability, light weight, high mean effective pressure, excellent economy, first cost, flexibility and quietness are controlling factors in about the order listed, while in the case of the car engine the relative order of importance is almost completely reversed and would read dependability, flexibility, quietness, first cost, economy, light weight and high mean effective pressure. Exception may be taken to the order given for cars, particularly as regards first cost and light weight, but since probably over 90 per cent of our total car production is designed to fit a definite price class, it will be realized that first cost has a predominant place in the design councils of the industry as a whole, and that light weight is of major importance only as it results in the reduction of the total amount of material to be purchased, thus reducing the material bill. Flexibility and reasonable quietness, like dependability, have come to be expected in all cars, and no car that does not give proper performance in these respects can hope to remain in public favor. I must confess that in placing economy below first cost I am reflecting the buyer's attitude as he, thanks to the manufacturer's reputation for never understating his case, will give greater weight to a known economy in first cost than to a promised economy in operation.

All Improvements in Airplane Engines Not Suitable for Cars

Airplane engine design detail that will increase dependability is immediately useful in cars provided it does not entail an abnormal increase in first cost. Airplane spark-plug development is an example. There are other minor ones that I shall not attempt to mention in detail here.

In general, light weight in airplane engines is obtained by the use of unusual light materials such as aluminum, regardless of cost, and by the reducing of all parts to the smallest section that will give a satisfactory dependability, with little regard to the labor involved in so doing. Aluminum has been generally used for oil-pumps, water-pumps, cylinders, and to a greater extent in carbureters, induction pipes and electrical equipment, than is common in car engines. A most significant example of the minimum section method of obtaining lightness is the all-steel cylinder used on the Liberty and some other airplane engines. I believe that the more extensive use of aluminum in car engines will be stimulated by this experience provided the price of this metal comes down to a point where, better machining allowed for, it can compare fairly well in cost of the finished piece with cast iron. There does not seem to be much reason to expect a landslide to light parts of the steel-cylinder variety as the cost of producing them by present methods is out of all proportion to the dividends they would pay in car service. Commercialization of the airplane engine will undoubtedly be along the lines of perfecting less expensive methods of manufacture for such parts. This may ultimately result in costs low enough to warrant their use in cars.

Many improvements contribute to high volumetric efficiency in airplane engines. Overhead valves are already used to a limited extent on car engines, but the overhead camshaft that is almost universal on airplane engines is practically unknown on cars outside the racing class because of the difficulty of getting a quiet and inexpensive form of drive. Very high compression and open exhaust are barred for car use because the former militates against flexibility and the latter is too noisy. Abnormally large valves and high lift are generally frowned upon in cars because of the tendency toward a lesser valve life and lack of quietness in operation. The unusual care taken to cool valves and spark-plugs in airplane engines in order to combine proper dependability with high efficiency usually involves structural features of the steel-cylinder type that are too expensive for cars. Abnormally large intake passages and carbureters are not usable in automobile engines because of the unsatisfactory effect on flexibility. On the whole, the engineer must be very cautious with the use in cars of design "stunts" that contribute to raising the mean effective pressure in airplane engines or he may find to his sorrow that he has sacrificed results that the public insist upon as necessary to satisfactory car performance. There seems to be no immediate promise of a general increase in the average mean effective pressure of car engines based on airplane experience.

The dead load that present-day airplanes can handle satisfactorily is relatively small. The power required to give them satisfactory performance is so high that a considerable proportion of this dead load must go to supplies, leaving only a small portion for useful load, or, if a large useful load is desired, the flight range is small. Economy of fuel is then of real importance. Good distribution, a carbureter setting as lean as will give full power over the engine speed range ordinarily used in flight but not so lean as to accelerate valve burning, and a sensitive means of reducing the fuel flow to an amount that will give a proper mixture with the lighter air at altitude, are the design details used to accomplish it.

The distribution and mixture adjustment experience is usable on cars, but it is obvious that the high-speed lean setting would not give proper flexibility. Oil economy is of much less importance from the weight standpoint, but it is carefully watched in airplane engines and methods for producing proper results in them will be useful in car design. Accommodating the oil supply to the load, which is very essential in airplane engines, has produced schemes for the interconnection of the throttle with the oil-pressure regulator that may find their way into cars of the higher grades.

It is a well-known fact that first cost has been largely overlooked in war airplane engine design where there was any military advantage to be gained by so doing. Such neglect obviously has not tended to produce design detail that could be used in cars, where first cost is of great importance.

Flexibility, or more particularly, speed range at full load, is relatively unimportant in an airplane engine which operates in the upper 20 per cent of the possible range with a given propeller for at least 90 per cent of the time it is at work. Flexibility being sacrificed to economy through the remainder of the range, it is obvious that we can learn nothing in connection with this car essential from airplanes.

In airplane service the noise of the propeller and the open exhaust drown out the mechanical noises of even the least quiet engines. Until these are eliminated, and there seems to be no prospect of getting rid of the propeller noise, airplane engines will continue to rattle and "slap" in a way that would drive the average car user to distraction.

Results of Airplane Design and Construction

A summing up of all this evidence indicates that there is very little ground for assuming that airplane experi-

ence will suddenly and immediately revolutionize cars. Market conditions being right, we may see an increase in the use of aluminum. If aircraft are commercialized to an extent that demands volume production of engines, we may develop methods of making the minimum section type of lightness that will make this practice usable in cars. There may be an increased tendency toward overhead valves and camshafts if the mechanism involved can be made sufficiently inexpensive and quiet. There are possibilities of minor improvements in carburetion and oil control and in some other details.

I believe, however, that the most important contribution which the airplane has made to the automobile is the stimulus to the thought of the industry as a whole that has resulted from the study of its design and manufacturing problems. Our war experience has set engineers to dreaming of ways to produce a light-weight result at moderate expense. It has taught an increased respect for good metallurgical practice as a necessary factor in successful design and manufacture. It has given the average manufacturer, who engaged in airplane engine building, a new conception of the value of high-grade workmanship and of the small margin of cost that, in many cases, separates it from the ordinary variety. I should say that in setting up new ideals of design and workmanship for the industry to strive toward, this study has given us an inspiration of far greater value than any design details could possibly yield.

The Discussion

J. G. Vincent:—I believe the most significant thing in connection with this paper and the two immediately preceding by Messrs. Marmon and Crane is the fact that three thoroughly experienced automobile engineers who have played a leading part in aircraft development during the war have written entirely independent papers on practically the same subject without, so far as I can find, a single note of disagreement. If I had written an independent paper on this same subject I would have covered exactly the same subject matter and made exactly the same statements, so that I am naturally in agreement with all the statements of these three gentlemen. I believe that these papers are particularly well written, and I think there is very little room for discussion. I believe a careful consideration of these papers by our members will probably save a lot of trouble and unnecessary experimental expense.

EXHAUST VALVE BURNING

INVESTIGATIONS have elucidated many facts that were hitherto obscure in connection with the burning of exhaust valves and throw light upon them.

It has been found that the temperature of an exhaust valve in the hottest portions is 1296 to 1331 deg. fahr. (700 to 750 deg. cent.), and that the temperature of the exhaust gases in the exhaust port is about 1296 deg. fahr. (700 deg. cent.). The valve is hottest, it was found, when the cylinder is working with the most efficient mixture; that is to say, when the maximum power is obtained with the minimum amount of gasoline. Whether the mixture be weakened or strengthened from this point, the temperature is immediately reduced. When the temperature is weakened, the power decreases at once; but the mixture can be strengthened considerably without any loss of power. The general impression that weak mixtures cause the valves to get very hot was not borne out by these experiments. It was apparent that the effect the mixture has on valve burning is controlled by the amount of free oxygen in the exhaust.

Chromium steel is stated to possess an advantage over tungsten steel in that it does not oxidize at ordinary working temperatures. The disadvantage in the use of tungsten steel is that under ordinary conditions the valves will scale and gradually become thin. Once the valve reaches the temperature at which burning commences, however, the difference between tungsten and chromium steels is not appreciable.

The question of tappet clearance was investigated, this, of course, being practically affected by the elongation of the valve at normal working temperatures. Tests carried out showed that this elongation is 0.014 to 0.016 in. A set of valves was run in with no clearance at all in the tappets when cold, so that at normal temperatures the exhaust valves did not seat by 0.015 in. It was found possible to run with the valves not seating by as much as 0.008 in. and still obtain a cool ring around the outer edges of the valves. Investigations showed that, with no tappet clearance in the exhaust valves when cold, the power was reduced by 1.5 per cent, and, further, that it was possible to run with only 0.005-in. clearance with no loss of power. In carrying the tests still further the tappets were adjusted so that the exhaust valves could never seat when cold by 0.01 in. As a result the power was reduced by as much as 15 per cent, and the exhaust valve became excessively hot.

In tests made to ascertain the effect of preignition by a spark-plug, it was ascertained that it is possible to burn valves of certain types in from 6 to 8 min. It was proved that a spark-plug which preignites under ordinary conditions causes the exhaust valve to run at an incandescent heat; and also that preignitions are greatly influenced by the amount of burning oil in the combustion chamber.

A case of preignition in an over-oiled cylinder has never been known, and actual experiments prove that if a plug commences to preignite this can be remedied immediately by syringing a little oil into the air intake.

It was found in the course of the tests that the water circulation has a great effect on the overheating of exhaust valves. When the water circulation is faulty, the first part to be affected is the exhaust valve. If the failure of the water circulation causes the spark-plug to preignite, which is a natural consequence, the valve is burnt in a few minutes. This is due to two causes, (1) failure of water circulation, and (2) preignition. When the water circulation begins to fail the water commences to boil, and consequently is lost through priming and evaporation, a trouble that it has not been possible thus far to obviate. As the engine continues to run conditions get worse, and in the hottest part, namely, that portion of the water-jacket around the exhaust valve, steam is generated which tends to force the water out in the front and consequently exerts a pressure against the water-pump which still further reduces the flow. By this time preignition has started, the power drops, and the valves commence to burn. The only way to prevent the trouble is to avoid running the engine with the oil too cold, as this reduces the quantity that escapes from the bearings, and in turn the quantity that reaches the pistons. Excellent results have been obtained by increasing the flow of water per minute through the cylinder jackets. Radiators and radiator piping offer by far the greater resistance to the flow of water, and any resistance in these should be carefully watched.

—*Commercial Motor.*

Peace Time Need For Airplanes[1]

I WAS called into aircraft production at a time when there was a great deal of discussion, a great deal of criticism and a great deal of blame. Most of it was totally and entirely undeserved. Aircraft production had to start at the beginning. It had to find a way from nothing, to meet the demands of the American people and be brought to a point that was beyond all reason. People talked of clouds of airplanes like tens of thousands of sparrows. It was just as impossible to realize that dream as it is to realize any kind of dream.

Aircraft had to be built slowly, carefully. They had to be built to conserve, first of all, the lives of those gallant boys who took these ships into the air. They had to be built sure. Everything that could be a menace to the life of these boys had to be taken out of them, if it was possible, before they were sent to fight across the line. The work that was done before me made it comparatively easy for me to win a good deal of praise to which I was not entitled. The work of my predecessors, the work of the aircraft manufacturers of the United States, was amazing in its competency. With singular devotion to the country, with great patriotism and with the greatest earnestness that I have ever seen in any body of men, our manufacturers had built an organization for the manufacture of aircraft that certainly has never been equaled. All it lacked was just time enough and some organization to drive it in the right direction and to finish it.

When I went to France in September our planes had just begun to reach the front line. There were a good many of them there. In the first day of the fight at St. Mihiel I went from one pursuit group to another and one observation group to another, talked with the boys and asked them how they liked the American-made planes. I think these boys will tell you that even then, after they had had them only a comparatively short time, there was not a single man of them who did not say that he would not take any other plane of a similar type into the air if he could get an American-built plane.

The greatest effort necessary to create aircraft was in the building of the engines, and is there anybody who doubts that the accomplishment of the American engine manufacturers was one of the greatest things done in the war? When the war ended there was no nation on our side of the war—and I am sure there was not one on the other—which would not take every engine we could build for it. There was not a nation in the war that did not want more of what we were making than we could build for it.

We did not do so badly. We built more engines and more planes, month for month, from the time we began than any nation in the war built from the time it began. We had more planes ready, and more engines ready, month by month, from the time we commenced than any nation in the war had, month by month, from the time it commenced. The American manufacturers of aircraft, the American engineers, with their ingenuity, their brains, their patriotic devotion and the tremendous work they put into it, were building so well and so fast that the day the armistice was declared there were 686 American planes at the port of embarkation that could not be loaded.

I hope that what has been accomplished in aircraft in war times will be duplicated to a great extent in peace times. I have no doubt that there is a great peace future for aircraft. I have no doubt that the men whose brains and money have been put into this industry will go on developing and perfecting it, making it so necessary to the life of the world that peace requirements will in time exceed the war requirements.

* * * I do not think I am over optimistic in believing that peace requirements will startle the world. * * * I should regret very much to have this pushed too fast. * * * It will not arrive in a day. I think that with care and caution, development and trial, the airplane can be made almost as necessary in peace as it has been in war. I believe it is in good hands. The manufacturers of this country who are in the aircraft business today will see that it is to their own interest to proceed cautiously, carefully, and with as few false starts as possible, and will develop the business on broad lines to bring it to the fruition it deserves.

I should think it would be clear to almost anybody that the necessity for the defense of a country like ours, with a great coast line like ours, makes a very extensive aircraft program a desirable thing. The science of aviation should be encouraged in every possible way. I would have an academy of aviation, just as we have a military academy at West Point and a naval academy at Annapolis. I would educate boys in aviation, strictly and almost exclusively, and with proper expenditure and direction, within 5 yr. from now an enemy fleet that attempted to reach the shores of the United States would be detected so far out at sea that it would be put out of business 300 or 400 miles beyond the shore. There is nothing in the nature of a dream about that. No one who studies what has been accomplished in aviation, and thinks what might be accomplished, can consider that at all visionary. Not deprecating in any way the great naval defense that is planned for this country, I should say that planes could locate an enemy fleet and the navy destroy it.

It would be a great pity if the brains in the aircraft organization—naval as well as army—should be dispersed. The civilians who have come into this work, able engineers who have gone thus far in it, should teach the younger generation all they know, and the great organizations that have been created under stress of war should not be dissipated. I do not advocate the building of great numbers of aircraft for military purposes. I think that is not necessary; but sufficient encouragement and employment can be given to the well-developed aircraft factories of this country to keep them in the business, to induce them to make discoveries and to do everything they can to promote the science of aircraft. Organizations should be kept intact, the men who are competent and who have done this thing should be kept together so far as possible. It would be a small expense, and God knows it might be a great measure of economy some day. Some people have criticized our work in aviation on the front; some say we have been too reckless. The French told me that our boys were too reckless; some of our own good friends have said the same—but, God bless them, that is what won the war: the fact that our boys were reckless. I saw them in France, when the clouds were low, and it was not a fit day for anybody to take the air, go out and fly 50 and 60 m. above the ground and bring back a complete record of what was ahead of them. General Pershing told me, when I talked with him on the second day of the battle of the Argonne, that no army had ever before gone out with the information as to what was in front of it as the American army did in St. Mihiel and the Argonne.

[1]From an address delivered at the dinner of the Manufacturers' Aircraft Association by John D. Ryan, former director of the Bureau of Aircraft Production.

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An Interpretation of the Engine-Fuel Situation

By Joseph E. Pogue[1] (*Non-Member*)

Annual Meeting Paper Illustrated With Diagrams

THE principal factors in the engine-fuel situation are the demand for liquid fuel and the adaptability of the internal-combustion engine, on the one hand; and the supply of crude petroleum, the gasoline-producing capacity of this material, and the substitute fuels in sight, on the other. Out of the interplay of these factors will come developments, focussed in the price of engine fuel, that will determine the future of the automotive industry.[2]

The Demand for Engine Fuel

The demand for engine fuel has been increasing over the past few years at an imposing rate. The nature of this expansion is shown graphically in Fig. 1. The construction program of automotive manufacturers, moreover, affords no prospect of let-up in the pressure of fuel requirement; on the contrary, the injection into the situation of a notable development in the capacity for truck production introduces an element that bids fair to overshadow even the tremendous automobile demand, while the item of tractor manufacture looms ahead with a fuel significance scarcely second in importance. If these matters be projected into the future unabated, it is evident that the supply of engine fuel will need to be doubled every few years. The automotive industry is young and vigorous, and its continued expansion will place an unexampled burden upon the engine-fuel resources of the country.

Adaptability of Engine Type

The automotive engine has developed and become standardized in its main features on the basis of cheap and volatile gasoline. Its improvement has for the most part followed the direction of convenience and performance, with secondary consideration to fuel economy. This trend has been sustained to the present time by the existence of a highly stimulated oil production, providing gasoline capacity in excess of gasoline demand. So long as this condition obtained, there was no need for the automotive industry to concern itself with considerations of fuel supply, but now, with the gasoline capacity of the country beginning to give indications of strain, while the gasoline demand is just fairly getting launched, the question arises whether the exigencies of the future will allow the engine type continued freedom of development in luxury directions, or will force adaptations to meet the exactions of the fuel situation.

Automotive apparatus is mechanically responsive to changing requirements, but its adaptation to new conditions is retarded by the time required to perfect mechanical developments and the counter advantage to be gained from quantity production and standardization, with their antagonism to change. So far-reaching and insistent, indeed, are the claims in favor of holding fast to established standards, that departures can be made only at great cost and in response to powerful reasons. Anticipatory action becomes peculiarly difficult in the face of these circumstances. Recognizing the strength of the factor opposing changes in engine type and seeking to force the fuel supply into channels fitting the established standards, we may examine the fuel supply with a view to determining if present engine standards can be advantageously maintained, and, if not, along what lines changes are likely to be made.

Supply of Engine Fuel

The engine fuel in dominant use in the United States is gasoline, a mixture of volatile liquids won from crude petroleum by a process of distillation.[3] Kerosene, fuel oil, lubricants, and various by-products are produced at the same time, and bear an intimate relation to gasoline, both as to production and price. The relative output of

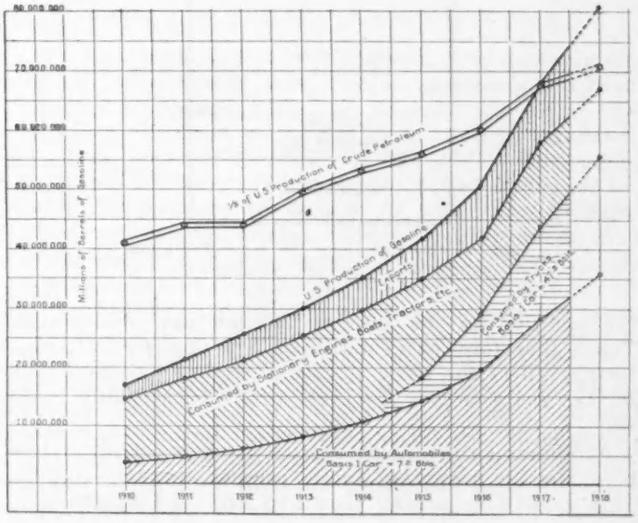

Fig. 1—The Gasoline Situation

This composite chart is drawn from data as follows: Crude production from U. S. Geological Survey; gasoline production from U. S. Fuel Administration and U. S. Bureau of Mines; automobile and truck consumption based on registration compiled by National Automobile Chamber of Commerce, and consumption factors worked out by War Industries Board (see manuscript report by M. J. Gillen on Regulation of Uses of Motor Cars, Gasoline, Rubber Tires and Rubber, Nov. 4, 1918). This chart is not exact in final detail, but is an interpretation of data approximately correct.

[1] Assisting director in technical matters, bureau of oil conservation, oil division, United States Fuel Administration.

[2] The validity of the conclusions presented in this paper depends upon the correctness of the writer's diagnosis in respect to four basic points: The domestic supply of crude petroleum, the significance of Mexican petroleum, the significance of cracking, and the adaptability of the automotive apparatus. An independent check upon these points, which will serve to substantiate, modify, or controvert the present argument, will be afforded by the other papers presented at the Fuel Session of the Annual Meeting of the Society, as well as by a study of the references given at the end of the paper.

[3] A small proportion of the supply is extracted from natural gas, but this does not largely affect the general situation.

these products in 1917 is shown in Fig. 2. The quantity of gasoline that the country is capable of producing depends upon the supply of crude petroleum and the gasoline capacity of this material.

Supply of Crude Petroleum The supply of crude petroleum for years to come depends upon the unmined reserve and the rate at which it may be won. The reserve in the United States was inventoried by the U. S. Geological Survey in 1908, in 1915, and again in 1918, with results shown in Fig. 3. The significant aspects of the results are two: The small size of the reserve, approximating 7,000,000,000 bbl. in 1918 (our annual production is over one-third billion), and the fact that in the past 10 yr., in spite of an exceedingly aggressive campaign of oil exploration, the decrease in the reserve has exceeded

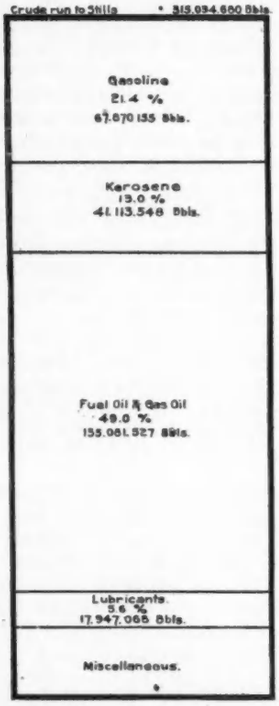

FIG. 2—GASOLINE AND ITS JOINT-PRODUCTS
Data from U. S. Fuel Administration

the addition to the reserve through new discoveries. Those, therefore, who count upon new discoveries to materially affect the basic situation overlook the fact that for ten years already discoveries have been failing to do so.

At the same time the production of crude petroleum has been steadily mounting to its present enormous figure. This growth in output, shown in Fig. 3, has been sustained, not primarily by the discovery of new oil fields, but largely by the cumulative tapping of an increasing number of rich spots in inventoried territory. There is obviously a limit to an output supported by such a train of circumstances; there are strong engineering and economic reasons for believing that the output of crude petroleum in the United States is nearing its maximum and that the country will soon pass into a period of slowing and more costly production.

Gasoline Factor The output of gasoline approximates[4] the supply of crude petroleum multiplied by its commercial gasoline factor,[5] which at the present time is about 20 per cent. This factor, like the supply of crude petroleum, is itself a variable figure depending upon the proportion of the crude supply subjected to refining, the natural gasoline content of this quantity, and the extent to which means are used for forcing the gasoline yield above the natural gasoline content. Obviously, as long as the natural gasoline is not fully extracted from the available crude, there is scant economic room for the development of round-about, i.e., more intricate, more costly means for producing gasoline. This was the situation that prevailed in the United States until recently; this is why natural-gas gasoline, cracked gasoline, and low-volatile gasoline are all recent commercial developments.

The proportion of the crude supply subjected to refining in respect to gasoline has been steadily increasing until the quantity so employed now approximates 95 per cent of the total.[6] Thus practically the whole output has now come to be requisitioned for gasoline production. This is to say that the readiest means for increasing the supply of gasoline, i.e., refining a progressively larger percentage of the crude produced, has been virtually forced to its limit; the "gasoline slack" within the crude production has been taken up. Thus the most potent circumstance that has thus far enabled the demand for gasoline to increase without a concomitant increase in price is no longer in existence (see Fig. 1). Further expansion in gasoline output will lie through more difficult avenues than that of merely increasing refinery capacity.

While dependent primarily upon the quantity of crude refined, the output of gasoline is at the same time a function of the average composition of the various crudes that go to make up the total supply. Since crude petroleum varies in its natural-gasoline content[7] from about 2½ per cent in the case of heavy, asphaltic oils to 25 per cent or more for light, paraffine oils, it is evident that the gasoline supply will be strongly influenced according to the dominance of the one or other type of oil. As the high-gasoline crudes were the first to be exploited in this country, the unmined supply of petroleum has been selectively reduced in gasoline capacity,[8] so that the crude production of the future will show a lower natural-gasoline factor than the crude supply of the past. While this matter cannot be expressed quantitatively, in very rough terms it may be noted that the high-gasoline crudes are about half exhausted, while the low-gasoline crudes, originally of about equal magnitude, are only about a third used up. In other words, the country's gasoline capacity is being drawn upon more rapidly; and hence exhausted more quickly, than is indicated by the condition of the crude supply viewed alone. This tendency was of no immediate consequence so long as it could be compensated by merely refining a greater proportion of the output of crude; but now, since practically all of the domestic crude is used for gasoline extraction, a decline in

[4]Because of the subordinate item of gasoline produced from natural gas, the relation is not an exact equality.

[5]The commercial gasoline factor is here used to represent the percentage of gasoline obtained from the crude consumed; the natural gasoline factor is the percentage of gasoline contained in the crude consumed. The first has increased until it has overtaken the second. (See Fig. 1) The terms are used in a general sense.

[6]A much smaller proportion, of course, is subjected to complete refining with the production of the whole range of petroleum products.

[7]This term is used in a practical, rather than a strictly scientific, sense.

[8]The gasoline content of crude oil has been known to decrease even during the life of a given pool, which is a tendency in the same direction as that occasioned by selective extraction in respect to separate pools and fields.

gasoline content can be offset only by shoving crude production to a higher figure than would otherwise be necessary, or else through a still greater use of means for wresting an unnatural percentage of gasoline from the crude obtainable.

The means for producing more gasoline than may be obtained by subjecting the total supply of crude to straight refining are: (1) increasing refinery efficiency, (2) blending high-volatile natural-gas gasoline with low-volatile refinery gasoline, (3) increasing the use of cracking in refinery practice, and (4) lowering the volatility of gasoline. All four means are increasing in use. For the sake of brevity, the first two may be passed over with the comment that, while important, they have quantitative limitations which prevent them from broadly affecting the situation. This is not true of the second two, the limitations of which are of a different order.

Cracking is a process attachable to straight refining, by means of which low-priced distillates such as kerosene and fuel oil are rerun under more rigorous conditions and partly converted into gasoline. Obviously, cracked gasoline costs more to produce than natural gasoline, because of a greater consumption of capital, labor, material and fuel, and is commercially possible only after gasoline requirements have approached the quantity producible by straight refining, and as long as there is a certain difference in market value between the raw materials used and the product turned out. The first condition has recently been attained, and there is already economic room for cracking; the second condition, if the prices of kerosene and fuel oil rise, can be maintained only by a proportionate increase in the price of gasoline. The prospective growth in the use of the Diesel engine, especially for marine service, with its high fuel economy in the consumption of heavy petroleum distillates, may be expected to lessen the advantage that at the present moment accrues to cracking. Although the price of fuel oil is limited by the price of coal, the advantages of oil over coal for marine service are so marked that fuel oil can probably rise to $5 to $10 per bbl. before reaching its limit. Another no less potent factor bearing unfavorably upon the aid that the automotive industry may expect from cracking, is the circumstance that the cost of cracking becomes greater as the percentage of gasoline demanded of a given quantity of raw material increases. This means, so to speak, that a little cracking may spread rather rapidly to all the crude refined, but much cracking will involve a step-up to a higher level of costs. In addition, the retarding influence that private control of patents will exert upon a widespread use of cracking processes should not be left out of account. Opposed to these unfavorable economic aspects of cracking, which offer relief only upon a basis of higher prices, is the matter of advance in cracking technology toward increased efficiency and lowered costs. Progress of this kind is undoubtedly in store, but advances under this head must work within the broad economic restrictions laid down above, and can scarcely be counted on to more than temper the price advances competent to maintain the requisite increase in cracking output. On the whole, then, there are reasons to believe that cracking, while of great importance at present, will under expanding use develop toxic properties, so to speak, which will limit its field of operations, if not ultimately remove it largely from the scene of action.

The fourth means for enlarging the output of gasoline independently of the production of crude is through lowering the volatility of the product. The less specialized the engine fuel in respect to volatility, the more can be produced from a given quantity of crude by the processes of refining in general use (see Fig. 2). By a change in character, the supply of "gasoline" can be enlarged, slowly or rapidly at will, without material refinery changes, until it is two to three times the present figure, even with no increase in the supply of crude. Since the materials requisitioned in such a change are the basis of kerosene and fuel oil, which can be replaced almost entirely by coal and its products, the transition may be made without a basic disturbance of the country's economic fabric and without setting up counter forces tending to turn back the tide, as would be the case in an over-dependence upon cracking. The practical limit to this enlargement, however, is set by what the standardized automotive engine will accept in the way of fuel; which is to say that this avenue of advance is wholly in the hands of the automotive industry. The progress of gasoline in this direction has already gone about as far as practicable under existing standards of mechanical equipment; if the fuel current finds an unbreakable dam at this point, the whole pressure of advance will be thrown back into the channels already reviewed. Inasmuch, however, as the past few years have seen the volatility of gasoline steadily decreasing, in spite of laws and the desires of the automotive industry and the public to the contrary, while engine design has already been forced to respond to this circumstance with superficial adaptations, it is apparent that the channels of crude production, cracking, etc., have already demonstrated their incapacity unaided to accommodate the rising flood of gasoline demand. If these mainstays of the automotive industry are failing to meet the issue now, it is hazardous to count upon complete relief in this quarter when the pressure focussing there is rapidly increasing.

Bearing of Mexico Upon the Situation

We have seen, so far as the petroleum situation in the United States is concerned, that an increasing supply of gasoline of present grade can be maintained into the future only through a growing use of cracking processes, involving material increases in the cost of production. But there are large oil deposits in Mexico which are believed by many to be capable of sustaining a North American supply of crude sufficient for all demands, even in the face of a slowing domestic output. What bearing does this factor have upon the engine fuel situation?

The oil-producing capacity of Mexico is certainly great, but the size of the underground reserve that will have to sustain production is largely an unknown quantity. The geological occurrence of Mexican petroleum is widely different from that of oil in the United States, and is of such a nature that the unmined supply cannot be readily inventoried. The output of Mexico to date has come largely from two wells of prodigious capacity which have been held in check, but one of these wells is recently reported to have gone to salt water. There are, in addition, political difficulties in the way of the exploitation of Mexican petroleum, while the output will have to go in part to Great Britain, whose subjects hold extensive interests in the Mexican fields, and to other foreign countries. Mexican deposits are also involved in a large and growing fuel-oil demand in respect to the merchant marines and navies of Great Britain and the United States, which alone will tend to exhaust them rapidly.

Of even greater significance to the engine-fuel situation, however, than the quantity of crude that Mexico

may be expected to contribute to the domestic supply, is the natural gasoline factor of this contribution. Unfortunately the natural gasoline content of Mexican petroleum is low, so that the more the domestic supply of crude is supplemented by imports from Mexico, the more the natural-gasoline factor of the entire crude supply is reduced, the more must cracking methods be called upon to sustain the production of gasoline. Thus, not only is the future of Mexican production a subject upon which adequate information is wanting, but, with the most optimistic assumption in that respect, the character of the supply is such as to be capable of sustaining an output of gasoline only upon a higher level of production costs[9] than now prevails. Thus Mexico, instead of offering a solution to the engine-fuel problem, promises only to accentuate the issue; especially as the sudden leap in production that is impending from this source will lend a strong color of assurance to the situation.

The statements thus far made in respect to Mexico may, without substantial qualification, be extended to include the oil fields of Central America as well, which will probably turn out to be heavy producers. As to South America, rather extensive explorations in most of the countries have failed to locate oil deposits of sufficient magnitude to bear materially upon the situation in the United States.

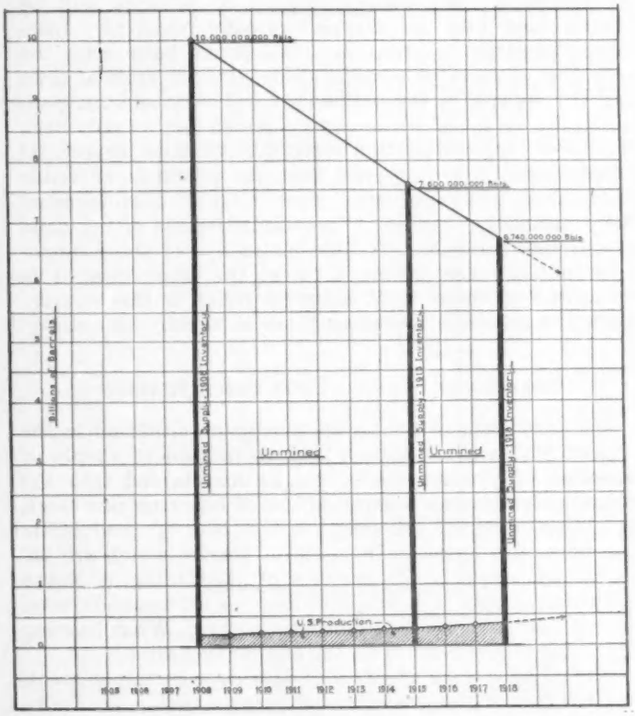

FIG. 3—THE DOMESTIC CRUDE PETROLEUM SITUATION
Data from U. S. Geological Survey

[9]This may not be strictly true of gasoline produced in Mexico itself as a by-product of fuel oil for a period following the establishment of large "topping plants" and in event of sustained production in that country of crudes containing appreciable quantities of gasoline; but imported gasoline can scarcely be counted on in quantities large enough, or sufficiently soon, to materially affect the situation in the United States.

[10]Gasoline can be sold cheaper than any competitor, because of the possibility of shifting part of its cost of production to the joint products.

[11]It should be remembered, however, that many years must elapse before a shale-oil industry can become established and grow to significant proportions.

SIGNIFICANCE OF SUBSTITUTE MOTOR FUELS

The petroleum industry is so firmly established and produces such a range of products other than gasoline, that no engine fuel of non-petroleum origin need be counted on as capable of displacing gasoline.[10] Substitute fuels are to be regarded as supplementary resources, capable of affecting the situation broadly only as petroleum relinquishes the field through exhaustion.

There are three substitute engine fuels in sight—benzol, alcohol, and shale-oil distillate. Benzol is now ready to compete with gasoline in a small way; alcohol and shale-oil distillate will be ready to compete only on a higher level of prices. As to resource capacity, benzol is a by-product of coal, and the quantity produced is dependent upon the coal subjected to by-product recovery; benzol will be manufactured in constantly increasing quantity, but the total supply can never fill more than a small part of the engine-fuel requirement. Alcohol and shale-oil distillate, on the contrary, are main products made from raw materials of almost unlimited availability; they may be produced to fill any need, however great, willing to pay the price. Whether shale-oil distillate or alcohol will eventually become the more important engine fuel cannot wholly be foreseen; but since shale oil is similar to crude petroleum and can be made to yield an analogous range of products, a shale-oil industry is certain to supplement and eventually to succeed the petroleum industry, and hence shale-oil distillate is bound to become eventually a prominent motor fuel.[11] Alcohol, on the other hand, is not so tied up with joint products, and its career as an engine fuel will be determined almost entirely by relative economy and its acceptability to engines evolving on the basis of oil fuel. If the engine type broadens so as to fit the petroleum resource, it will at the same time be prepared to receive the aid that benzol, shale-oil and alcohol may be called upon to render.

On the whole, then, there is nothing in the substitute engine-fuel situation that would dictate to the automotive industry a policy differing from that determinable upon the basis of the petroleum issue. The substitute fuels remove any physical limit as to the quantity of engine fuel that may be produced; they offer greater assistance to the situation if present standards are less rigorously adhered to and automotive apparatus becomes adapted to a less volatile fuel than gasoline; they set the bounds to which the price of engine fuel of petroleum origin can advance—a very rough approximation of this figure being relatively 50 to 60c. per gal:—suggesting, therefore, to the automotive industry an increase in thermal efficiency competent to offset the advance in price which the substitute fuels will permit and the petroleum situation will occasion.

COORDINATION OF THE INDUSTRY AND FUEL SUPPLY

The foregoing analysis of the resources and technology underlying the prospective supply of engine fuel indicates that the continued growth of the automotive demand will soon force either an extraordinary dependence upon cracking, with concomitant increases in production costs, or else a change in the character of the fuel so as to include more and more of the material now going on the market in the form of kerosene and fuel oil. The first adjustment is limited by the physical capacity of cracking, which is largely an unknown quantity, and the extent to which fuel costs can rise without involving cur-

tailment in the growth of the automotive industry. The second solution is dependent upon the extent to which automotive apparatus may be adapted to consume a fuel less volatile than gasoline. Running through each solution, and serving to contribute to each, is the extent to with the thermal efficiency, or fuel economy, of the automotive apparatus may be increased. The more rigorously the present standards of low economy and specialized requirements are adhered to by the automotive industry, the greater the weight that will fall upon cracking, the greater and more sudden the inevitable rise in fuel price and the graver the danger of an industrial reverse.

The fuel resources in sight indicate that a normal balance between supply and demand will eventually be reached, irrespective of the policy of the automotive industry, but the adjustment will result in a basis of price and character different from that now prevailing. The danger in the situation is not that of a permanent breakdown in fuel supply through exhaustion, but of a period of enforced readjustment to new conditions of fuel supply, which may come so suddenly as to catch the automotive industry unprepared and in consequence impose a serious handicap upon its prosperity, if it does not precipitate industrial disaster.

The situation is serious, indeed critical, not only because the period of readjustment is apparently almost upon us (see Fig. 1), but because there are many aspects of the situation that tend to hide the real issues and to lend a false sense of security to those filled with an excess of optimism. American economic experience affords no parallel to the present engine-fuel situation; as demand in the past has almost invariably conditioned supply in American economic practice, it is an easy assumption that this will continue to hold in unabated vigor. New discoveries of oil pools are constantly coming into prominence. While the outlook for oil production never before appeared brighter, one easily overlooks the fact that each new pool, in proportion to its magnitude, adds to the unstability of the engine-fuel structure. At this very moment of writing, gasoline is piling up in storage and it is quite possible that before the winter is over the price will decline slightly. This may readily be accepted as controverting the whole argument of the paper, if the circumstance is not recognized as an inevitable reaction to a coincidence of season and post-war industrial readjustment. Upon all this come widely heralded announcements of new fuels, with extravagant claims and secret formulas, boldly promising at one stroke an easy solution of one of the most complicated industrial problems this country faces today. There are indeed specious arguments for sustaining conclusions quite the reverse of those arrived at here. While one series of circumstances is operating cumulatively to render the engine-fuel situation more and more unstable, another set is serving to hide the real issue to the last.

There is scant hope, at this late date, that the automotive demand will be brought into stable adjustment with the engine-fuel supply with results wholly conducive to the prosperity of the automotive field, but such difficulties as lie in store may be tempered if the industry as a whole recognizes its responsibility in this matter and acts accordingly. The exigencies of the fuel situation now urge, but shortly will demand, that the automotive industry work toward greater fuel economy and at the same time adapt its mechanical equipment to handle a less specialized fuel than gasoline. The first can be accomplished in some degree through car design, but in the main must depend upon engine changes in favor of greater thermal efficiency. The second can be accomplished either through the development of equipment not dependent upon fuel of high volatility, so as to permit the supply of "gasoline" to expand easily, or else by inducing the engine-fuel supply to bifurcate into gasoline of the grade at present reserved for passenger cars, and heavier distillates to be drawn upon by trucks, tractors, etc., fitted with semi-Diesel or other type of engine suited to such fuel. Apart from the disadvantage of greater costs involved in the production and distribution of two specialized fuels in the place of a single product, and the practical difficulty of unloading the problem on the heavy-traction section of the automotive industry, the second expedient would in reality mean merely the turning over of the raw materials of cracking to a counter-demand and would leave the gasoline problem still in acute need of attention. So the economics of the situation, the dictates of resource limitations and human needs, point to an automotive engine evolved into a type fitted to gain not only higher efficiency from the fuel consumed but greater economy in respect to the activities involved in the production and distribution of the fuel. The answer then is: Greater thermal efficiency in the engine and means for gasifying liquid fuel without requiring that it first be converted by a costly manufacturing process into a highly volatile product difficult to store and to transport.

Summary

(1) The automotive industry is working without due regard to the engine-fuel situation.

(2) This situation is an integral part of the automotive situation and should not be left out of account.

(3) Owing to the pressure of automotive demand, the supply of engine fuel is in course of change, both in respect to character and price, with danger of precipitant alterations; there arises in consequence a fuel problem which cannot be adequately solved without the active participation of the automotive industry.

(4) An analysis of the problem is as follows:

(a) The domestic production of crude petroleum is nearing its maximum

(b) The natural gasoline content of this supply is lessening

(c) Mexico offers no relief competent to solve the issue

(d) Substitute fuels need not enter into present consideration

(e) The supply of engine fuel can be maintained only through an extraordinary dependence upon cracking or through changes in engine type

(f) Cracking cannot meet the issue at a favorable price

(g) The burden, therefore, falls upon the automotive engine, which must consequently so adapt itself as to gain higher thermal efficiency, and to use less specialized (less volatile) fuel

(5) The automotive industry should therefore at once, as an emergency measure, take steps to shape its development in the direction of increased fuel economy and less specialized requirements as to fuel, establishing for this purpose centralized machinery for studying the problem in full detail; for keeping the industry informed of every development in the situation; for coordinating re-

search and design in the competing units of the industry, and for conducting basic lines of research not now adequately encompassed by individual agencies.

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The Discussion

B. B. Bachman: In this paper the author has given a general analysis of the trend of the automotive industry in the increasing production of apparatus calling for volatile fuels and the probable limitations on the part of available resources to meet this demand. The complexity of this problem and the contradictory evidence which has been presented from time to time make it difficult for one not in intimate contact with the subject to evaluate the arguments advanced and the conclusions arrived at.

However much the author's opinion may be contradicted by other authorities, he should receive due credit for having the courage of his convictions in calling attention to what he conceives to be a danger to the future of the automotive industry. On the other hand, it is unfortunate that general discussions and pessimistic personal opinions on this subject are frequently abstracted by the press as affording news of a sensational nature which is very often misinterpreted by the untechnical reader. As much may be said for the publicity given in the same mediums of the many supposedly infallible remedies which have been proposed. In both cases the result is only to becloud the main issue.

The internal-combustion engine in the form used in automotive apparatus is unquestionably open to criticism from the standpoint of the thermal efficiency obtained. Lack of economy in installation in passenger vehicles and to a lesser extent, perhaps, in heavier vehicles, can also be charged with some propriety to the demand for flexible performance which has been created in introducing the product to the public and in fostering the competition between various manufacturers. Nevertheless, however much we, as engineers, may recognize the defects of our product and the lines along which progress must be made, it is not wise to blind ourselves to the advances we have made and the standards of performance which have been created. From the standpoint of light weight, durability, flexibility, power output per pound of material, cost and adaptability to its purpose, the modern gasoline engine is a marvel of mechanical achievement.

Quoting from the paper, the author tells us "American economic experience affords no parallel to the present engine fuel situation." We may as aptly say that history affords no parallel for the condition with which the author confronts us of creating a new device to function in competition with a machine that is so satisfactory, for the present, at least. If the fuel were known, together with its characteristics and peculiarities which would insure a stable condition of future supply, it would be more nearly possible to predict what the solution of this problem will be. Should it be necessary to curtail any of the excellent features of the present engine as outlined briefly above, it would appear that only cooperative action between the, at present, competitive units of the industry would afford a possible means of successful introduction. Of course, if any individual by a stroke of genius should develop an engine which in addition to the present features possessed the advantage of offering a successful solution to this problem, he would, to use a colloquialism, be "sitting on the world."

It seems unthinkable that progress once inaugurated and carried to such a high state of development should be halted. The author says: "The danger in the situation is not that of a permanent breakdown in fuel supply through exhaustion, but of a period of enforced readjustment to new conditions of fuel supply, which may come so suddenly as to catch the automotive industry unprepared and in consequence impose a serious handicap upon its prosperity, if it does not precipitate industrial disaster." It seems to me that the consequences of such a catastrophe would be infinitely more far-reaching. The portable self-contained prime mover developed in the modern internal-combustion engine has wound itself so intimately into all our activities that it requires no great stretch of the imagination to conceive that its withdrawal would menace the structure of economic and political organization upon which rests the security of our civilization.

Merely to say a thing is unthinkable or impossible does not dispose of the question, and this leads me to call to your attention the fifth point of the author's summary. While there may be a division of opinion on the degree to which the deductions reached in the paper are true, there does not seem to me to be any doubt as to the wisdom of following this bit of constructive advice. It only remains then to consider the machinery by which this research shall be carried out. The nature of the problem would seem to indicate that the Society would be the organization best suited to bear the burden of a large part of this work, and the Standards Committee the organization through which it could be successfully accomplished.

It is well to remark, however, that this problem presents some novel features not at present encountered in the Standards Committee activities. First in practically all of the present work the problems are in the line of coordinating and establishing practices and methods of construction which will simplify manufacture and bring about economies by the elimination of an excessive and

unnecessary variation in form and dimension of materials and parts of apparatus. This work can well be accomplished by the cooperation of men who are primarily engaged in other activities and who devote only a relatively small proportion of their time to their committee work.

It is obvious that such a procedure would not suffice for the problem under consideration. The committee to handle this proposition, by reason of the necessity of investigating a large amount of data and interpreting it, should include men competent by training and experience in the technique of the production and use of oil fuels, so that the results of their work would bear the stamp of authority. To do this properly and promptly will require more than the ordinary amount of committee work, and it accordingly becomes a problem as to how to secure the services of men of the caliber required. In addition to this, to complete the work it will be necessary to investigate substitute fuels, methods of fuel production, apparatus for using these fuels, and new methods of engine construction which, if followed by a verdict as to their value, will constitute a radical departure from our present practices and policies.

HUGO C. GIBSON:—Dr. Pogue carves the meat of the subject very neatly in the section of his paper entitled "Adaptability of Engine Type." It is only regrettable that he does not go further and tell us just how to accomplish the necessary end.

The controlling factors of carburetion are getting the heat in and getting it out for power and economy. Just so long as we could get gas in, because of a highly volatile liquid, the gas of which did not readily condense when cooled, there was no difficulty in following the law that the more gas and air we put in the more power we got out. The number of British thermal units generated was higher, the temperature in the cylinder was higher and the equation

$$E = \frac{H - Hl}{H}$$

was high. Today the endeavor is to put the mixture in as cool as possible because a cool mixture means a small engine for the power developed and a small engine means high load weight to vehicle weight ratio, incidentally meaning a high profit to turnover ratio to the manufacturer.

But the factor of greatest importance today is that our gasoline is not what it was and will not stay put as a gas at the temperatures at which we would like to introduce it into the cylinder. It must be hotter or it will not vaporize or will condense. Fuel in the cylinder which is not in the form of vapor will break down and deposit heavy oils and carbon. The fuel value is lost to the extent of the heat units contained in the deposited material; so we lose the extra power we expected to get from the use of a cool mixture.

Since we cannot put the desired number of usable heat units when hot into the cylinder of small capacity we must, to obtain the desired amount of power, use cylinders of larger capacity or higher engine speeds.

Higher engine speeds mean reduced volumetric efficiency which must be made up by having the ingress and egress of gases easier. Ingress is assisted materially by increase of port area in sleeve-valve engines and multiplication of valves in poppet engines. Egress thus far appears to be treated in the same manner, ignoring interaction overlapping of exhaust-valve timing, a detail of the utmost importance, recognized and cared for by makers of six-cylinder engines but neglected in the case of four-cylinder units. It is a fact that four-cylinder and all engines are immensely improved by complete exhaustion, though arguments are advanced that the heat of trapped exhaust gases aids vaporization. It might, if the time element were greater; if the unvaporized fuel in the cylinder were exposed to heat for a longer time.

I would urge the thought that time is the essence of the conversion of modern, and more so of future, engine fuel into gas and conclude by enunciating the cardinal factors controlling the effective use of the petroleum automotive fuels.

The fuel in mixture must be treated gradually by stages.

After vaporization the low limit temperature of the mixture should be maintained.

The passages to and from the engine must be large enough throughout to provide high volumetric efficiency.

The cylinder must be larger or the speed higher than formerly.

The exhausting function must be highly effective. Better mufflers must be used.

Cylinders, after complete exhaustion, must not be refuges for vagrant polluting gases from other cylinders.

Thus we will satisfactorily utilize the fuels that we can have.

MR. POGUE:—No intent is had to disparage the internal-combustion engine. The attainments on this score are, indeed, one of the notable achievements of the present century. The point may be fairly made, however, that the internal-combustion engine has not developed rapidly in respect to thermal efficiency for the simple reason that an abundant fuel supply is not conducive to such a development. If fuel stress develops, or may be anticipated, then the engine will duly respond to the new conditions. Up to the present, the engine has conditioned the fuel; it is an open question whether the fuel may not soon have an influence upon the engine. It is here that study and planning ahead are needed to coordinate engines and fuel, which are already beginning to work somewhat at cross purposes.

DISCUSSION AT KANSAS CITY

The following discussion was had at the Kansas City Tractor Meeting, Feb. 27, where the paper was also presented. In this case the fuel question was discussed by Dr. Pogue, with especial reference to the tractor industry.

M. BECK:—What does the shale-oil industry look like?

DR. POGUE:—I should have mentioned the shale-oil industry, because, without question, it will be the successor to the petroleum industry. So far as the automotive industry is concerned, it can forget the shale-oil industry, as the coming in of shale oil, when the time arrives, does not materially affect the issue, since it is chemically and physically analogous to petroleum. The automotive industry will not know when the shale-oil industry comes in. It will wedge in with petroleum, as petroleum falls off; so it seems to me that shale oil in the offing does not affect the problem as it presents itself to you at the present moment. The matter of alcohol, which is a second substitute fuel, is very difficult to foresee, because alcohol is a single product, whereas engine fuel from petroleum or shale oil is tied up with other necessary products, such as lubricants. This relationship would seem to indicate that shale oil distillate *must* come on the market, whereas alcohol *may*. However, so long as petroleum and its successor can meet the demands it will be difficult for any

product, single-handed, to come in and compete, for the simple reason that when you produce a series of joint products you can sell one of them as cheaply as you please by shifting the price of the others. This circumstance has a very practical bearing when a product like alcohol tries to displace gasoline.

CHARLES B. PAGE:—Will Dr. Pogue discuss the characteristics of the heavier oil which the tractor may be obliged to use some time in the future, or should be prepared to handle successfully?

DR. POGUE:—Half of the petroleum at the present time is turned into fuel oil, which is a product heavier than kerosene. The development along that line will mean the development of an engine radically different from the present type of engine, such as the Diesel or semi-Diesel. Whether such an engine is applicable to tractors I am not prepared to say, although quite probably it is. There are possibilities of great promise, too, in connection with the gas turbine, which, if I understand the matter correctly, can use practically any type of liquid fuel. The situation depends entirely upon how far the internal-combustion engine has been developed toward ultimate perfection. I rather like to take the view that even these mechanical matters are in course of evolution, and if you recall the length of time that elapsed between the first crude steam engine and the present efficient steam turbine, you will see that the internal-combustion engine, at least as regards its intensive period of development, is still very immature. Moreover, up to the present there has been absolutely no incentive, no economic reason, for the internal-combustion engine to develop in the direction of increased fuel economy or in the direction of using a less volatile fuel than gasoline, because there was plenty of cheap gasoline. We are just at the present time beginning to meet a different situation, where the pressure shaping the evolution of the internal-combustion engine is of a different kind. The internal-combustion engine seems to me to be a very notable achievement; indeed, one of the outstanding accomplishments of the twentieth century, but its attainments have been in the direction of flexibility, power, ease of operation, and so on, and have not taken the direction of fuel economy and efficiency, for the very simple reason that there has heretofore been no cause for development in that direction. Now, if a cause has arrived, as I believe it has, the engine will follow that course of development. I believe that the time has arrived in American economic practice when we can use our knowledge for seeing these things in advance, and, by planning ahead, make a gain over what we would have if we left things to their normal, untrammeled course of development. It seems to me that is what science is for.

MR. FOLGER:—Is it not possible that shale oil can be separated by distillation processes or by cracking into fuels suitable for the automotive industry?

DR. POGUE:—It is very probable that shale oil will yield roughly the same range of products that petroleum does.

MR. FOLGER:—Is it not true that the shale field offers an almost equal supply to our present fields when fully developed?

DR. POGUE:—The quantity of oil which the oil-shale deposits in this country are capable of producing is astounding. I started to say that the petroleum resource looks insignificant compared to the oil-shale resource. There are centuries of oil in shale, but you must remember that the production of oil from a lean resource like oil shale, which has to be mined and then distilled before you get it to the state of crude petroleum, means that the products, in all probability, can come on the market only at a much greater production cost than that of petroleum. Otherwise, they would be on the market today, and they are not. Petroleum is a creamlike resource, and so long as you can go out and drill a hole in the ground and have your oil come out so rapidly that you can scarcely take care of it, shale oil means nothing. When that period is over shale oil will come in, but you have a more expensive proposition to meet there, and you can meet it very easily by merely increasing your thermal efficiency. I was surprised, when I first went into this matter. I had a suspicion that the internal-combustion engine was not as efficient as it might be in respect to fuel economy, but on every hand competent automotive engineers tell me that it would be possible to double or treble, or even quadruple, the mileage obtained from engine fuel, not exactly in the present engine, but by devoting attention over a period of years to that result. If that be the case, as these greater production costs come in they can be tempered and nullified by increasing the efficiency of the internal-combustion engine. There is a give-and-take relationship between the engine on the one hand and fuel on the other, and we will not get the maximum economy until those two things are brought into coordination. If there were one big industry in this country producing all the oil and making all the engines, there would be no fuel problem at all, but such is not the case. We have the oil industry, which is composed of a number of units, and we have the automotive industries also composed of a number of units. They are competing. They can cooperate only with difficulty, yet for a favorable outcome they must be coordinated. We have come to the time when this question of coordination must be settled, and it seems to me that a function as large and as embracive as that cannot be carried on by any other agency than the Government. I conceive it to be the duty of the Government to stand ready to effect the coordination of technology, without which proper progress cannot take place; and, moreover, without which this country cannot keep pace with the European countries which are doing or are planning to do this very thing.

MR. FOLGER:—If the engine builder designs a more efficient engine, and the oil fields produce double, treble or quadruple the amount of shale oil from the shale fields, the result will be an item in the automotive industry. It is merely a matter of price that is keeping them out.

DR. POGUE:—In 10 yr., if not sooner, I expect to see a large production of shale oil. The fact that it will cut a figure in the future does not necessarily affect the situation today, because so far as the present is concerned you may regard shale oil as part of the petroleum resource. All that shale oil does is to assure you that there will be plenty of oil, but it does not assure you that there will be cheap oil. There is no danger of exhaustion. Shale oil will last for many centuries. You need not be pessimistic on the question of exhaustion. It is simply a matter of securing more or less economy, which means everything. If a man cannot afford an automobile at a certain price of engine fuel it means everything to him whether that fuel is above his level or below it.

MR. FOLGER:—It is well known that the cost of fuel as a part of the total operation of a car is very small. It is one of the smallest items in the cost of passenger cars.

DR. POGUE:—In the event of the cost of fuel doubling it becomes twice as important.

MR. FOLGER:—Even at that it is very much less than the cost of tires, supplies, etc.

MR. WALKER:—A man will buy a passenger car, and it does not make any difference what it costs him to run it. When he buys a car to do business with he very carefully analyzes the cost.

DR. POGUE:—According to the figures we gathered, the average fuel consumption in running a motor truck is 47 bbl. per yr., and at $8 per bbl. the annual fuel cost is a considerable item.

H. C. CHASE:—It is very apparent that gasoline will not always be available in the form that we know it today, although we may have it at a price very much greater than we now pay. Is it not very apparent that the automotive industry as a whole should immediately undertake the development of engines that will use a wider range of fuel? These may not be Diesel engines, they may be an entirely different type, one that does not run on cycles, but I firmly believe that it is the duty of the automotive engineers of the country to undertake this task at once. Some years ago it became apparent that a very fine grade of coal, that is a pulverized form or the smaller sized lumps, could be used for steam purposes. It was thought that this would effect great economy in the coal supply. As a matter of fact, since the coal could be had at a lower price, the demand was so much greater that within a few years the fact that a larger source was available had been offset. It seems to me most important that engineers today realize the need for increasing the thermal efficiency of engines and seeking for one that will adapt itself to a wider range of fuels.

C. J. B. LUCAS:—Fuel is a vital factor in the sale of tractors, trucks and passenger cars in South America, and it is absolutely necessary, if American manufacturers want to get their share of that business, that they be able to design an engine that will burn almost any kind of fuel. The people at Buenos Aires pay between 62 and 75 cents per gal. for gasoline. That is the one factor that is keeping American and all other tractors out of the South American markets. Until American manufacturers design an engine that will burn a low grade of fuel which will not cost over 30 cents per gal. they will have a hard time getting a fair share of that trade, because they are very loath to change.

CAPABILITIES OF THE SUBMARINE

A SUBMARINE is a slow craft, and is dependent entirely on her submerging qualities for defense. She is not built to fight with surface ships on the surface, and prudence as well as tactics should prevent her from doing so.

The present day enemy submarines are built and tested to stand the water pressure existing 300 ft. below the surface, but when submerging they do not often go down more than 200 ft. A submarine can lie still on the bottom, under favorable circumstances, for perhaps 72 hr., provided the depth of water is less than 300 ft. Whenever a submarine is submerged and not lying on the bottom it is necessary for her to keep moving to stay down, the minimum speed possible being about 1½ knots, and at this speed a U-boat may remain submerged for 18 hr. At full speed submerged—10 to 12 knots—a U-boat can remain submerged for only 2 hr. without coming to the surface to recharge her batteries. In recharging batteries, which must be done on the surface, a submarine can lie still or she may go ahead slowly on one engine and charge her batteries with the other. In this latter case one shaft is run by the Diesel engine on it, with the propeller connected and the motor disconnected.

German submarines are propelled on the surface by Diesel heavy-oil engines; when submerged, by electric motors drawing current from storage batteries. Their economical speed, both surface and submerged, is 6 knots, and they usually cruise at that speed. A submarine may cruise submerged, awash or on the surface. Awash means that she is running with all hatches battened down and everything ready for diving instantly. She can submerge from this condition, shift from her engines to her motors and disappear completely in about 30 sec. In surface trim she will have hatches open, possibly have her radio masts up and some of the crew on deck, but she can submerge in about 90 sec. from this trim.

The submarine submerges by her trimming tanks and diving rudders. When she is cruising on the surface she has positive buoyancy, and to submerge she admits sea water to her trimming tanks, thus changing to negative buoyancy, and inclines her diving rudders down so that she will dive more rapidly. In coming to the surface she merely inclines her diving rudders upward and slowly forces the sea water from her trimming tanks.

The torpedo tubes in a submarine are in the bow and in the stern so that the submarine must be pointed to point the tube. The German submarine torpedo is a short-range projectile, designed to be fired at from 500 to 700 yd.

A submarine can and usually does fire her torpedoes while she is completely submerged, although her periscope may or may not be above the surface at the time. As far as the actual firing of the torpedo is concerned, it is not necessary for the periscope to be shown at all. It will be like shooting in the dark, however if the periscope is not shown from time to time while making an approach to observe and estimate the target ship's course, speed and distance. That part of the periscope which appears above the surface is only a little more than 1 in. outside diameter and 10 in. in length, and it is raised and lowered instantly by a small electric motor. Sometimes that part of the periscope which is to be shown is nickel-plated and kept bright in order to reflect light rays; at other times various methods of camouflage painting are resorted to in order to make it almost invisible.

Any ship which has a speed of more than 15 knots and travels at her best speed through the submarine zone is practically safe. Only a few ships have been torpedoed while actually making 15 knots or more. It is sometimes possible for a fast ship to avoid a torpedo when the torpedo wake is sighted early enough, but in most cases where ships are reported to have dodged a torpedo, the torpedo would have missed them anyway. Unless the torpedo is running on the surface it will be a long distance ahead of its wake, because the wake is formed by exhaust air bubbles which rise to the surface slowly, and no ship can turn quickly enough to avoid a torpedo approaching at 30 knots unless the latter is a long way off. When a torpedo strikes a ship it will make a fairly large hole, but most ships sink because the water admitted by the first hole causes other bulkheads to give way, thus flooding the entire ship.—*Sea Power.*

Addresses at the Home Coming Supper

THE afternoon technical session of the Society held at the Hotel Morrison, Chicago, Ill., Jan. 30, was followed by what was termed a Home Coming Supper. About 400 members and guests representing various automotive industries were present. The speakers of the evening included H. H. Merrick, president Chicago Association of Commerce; Col. Chauncey B. Baker, Motor Transport Section, Quartermaster Department and President Kettering. E. E. Peake, executive secretary, National Automobile Dealers' Association, acted as toastmaster. The remarks of these speakers are printed substantially in full on the following pages.

ADDRESS OF E. E. PEAKE

THE automotive industry, which is yours, has just slipped in on us. It is getting bigger and bigger, and I think we who are interested in it scarcely realize as yet the magnitude of it or what it is going to mean. It is my belief that the invention of the automotive powerplant marks this as one of the really big creative periods of the world. Self-moving vehicles, in the air as well as on land, will undertake all kinds of transportation. In 25 yr. from now there will be permanent highways throughout the country, electric-lighted, and of course, policed. There will be the farm houses all along these roads, electrically lighted. Every farmer will have an automobile and few will have a horse. There will be union freight stations for truck haulage. Chicago will have one three times as large as any such freight station now in the world. There will be passenger stations also.

Just now we are all talking about reconstruction. We don't know much about it and several of us hardly know what it means, but I for one think it is fine. I have fallen into the habit of using the word along with camouflage and fuselage, words that we like to say, but to be serious for a moment, the length of time needed for reconstruction will be measured by the use the business world makes of the car, the truck, the tractor and the airplane in bringing life back to normal conditions. Business in this country cannot walk. It cannot follow a horse. It must go on wheels propelled by engines, and I am sure that we shall all watch and work for results. Those who are in the business need no encouragement to push their particular work.

ADDRESS OF H. H. MERRICK

THE things accomplished by the men of your profession and by this splendid organization during the war are well known. When the history of this war is written the Society's deeds will appear in glowing words. I know something of the proportion of your men who have given of their time and service, brain and effort, to war work. When, perhaps during our generation, the causes of this war, the reasons that led up to it, the history of the war itself and the analysis of those things that made for the winning of it by the Allies shall all be set down, we shall find that full credit is given to what I consider the fundamental reasons for our success—the wonderful spirit of America, the spirit of sacrifice, of willingness to serve, of readiness to do whatever seems the best thing to do. The breaking of the morale of the Germans was not due alone to the magnificent valor of the men in the armies of the Allies and our boys, but to the sudden, complete realization that our nation over here had only begun to fight; that the civilians back here, 107,000,000 of them, were approximating an efficiency never before known in the world; that great fleets of airplanes for which you men were chiefly responsible would in a short time be ample to wipe Germany from the face of the map; that our tremendous production of trucks and of foods, the cereals and fruits of the soil, made it humanly impossible for any end to come save victory, as our flag went forward.

It is said that republics are ungrateful; that things are soon forgotten. One of the chief industries of today in our United States is known as the investigating committee. I happen to be before one at this time, temporarily relieved that I may address you, and week by week, and month by month we shall hear of these investigating committees made up of Congressmen, going about looking into causes of "the death of the horse that died last year," instead of considering the ones that should lead to our prosperity in the future, and the country-wide problems that lie ahead.

So you men as you go back all over the United States may well carry the message. This morning we picked up the papers and learned of the embargo by Great Britain. Possibly it is necessary; perhaps it is wise from the standpoint of Great Britain, which says that we shall not export to the British Empire manufactured goods of certain classes after midnight tonight save upon a special permit. Very likely it is the result of a policy worked out during the past 2 yr. and put into effect by cable, so that perhaps not one-half of us know that it is to go into effect at once.

No more machine tools are to be shipped abroad, no more manufactures of iron and fabrications of certain classes; and then you are told, for all of you men are interested in foreign trade, that there is a little freight war on in favor of British ships, and three weeks ago, by cable, the freight rates were reduced 60 per cent as against United States shipping.

If I were an Englishman I would be proud of that. I am not quite so proud that we are not prepared for this embargo. Shall we ship all of our raw materials and let the English manufacture them and ship them in British bottoms throughout the world while we sit idly by waiting for an all-wise Providence to descend upon us? Is that the way that you built up the automobile industry, or turned out the Liberty engine, or solved the problem of the airplane? I think not.

The wheels of industry must go forward. Your automobile industry is making strides; you need men. I was told this afternoon that a very considerable number of the factories that you represent need high-priced men; that there is an actual call tonight for about fifteen or twenty men of the type of general superintendents and chief engineers, the high-grade men who are never secured through employment agencies or the public press. We are getting back right now the men who can qualify for these and other special positions. It pleases me mightily to be told that there are many firms in need of twenty men. That is good, healthy information for the public and it is encouraging for the public to know that more tractors, cars, gasoline engines, parts and accessories are needed than ever before, and that you are planning to run double shifts, in some cases day and night.

I have watched you men through the war. You have been regulated; you have had to shut down because of

war needs. You responded well, turned from the manufacture of passenger cars to trucks, to airplanes or airplane parts, and there was not a murmur. You have swung back more quickly than others from war to peace, you have a cheer on your lips and you are here in convention! That is the spirit of America, the spirit of which we are all proud.

We do not need to whine; we do not need to look to anybody or any nation in the world. We are sufficient unto ourselves, masters of our own fate, if we have the courage of our convictions and the courage that animates our soldiers abroad and at home. The Germans have said it. It was not the jab of the bayonet nor the shot of the gun that brought victory; it was our manifestation of courage and principle and driving force.

Now let us drive this nation ahead as it has never been driven. As for the politician who wastes time in investigating the horse that is dead, let us scrap him as we scrap a machine that is worthless and a liability. Let us get rid of some of our dead wood and put in live men. Let us do the thing that we think is right and we shall have such business prosperity and success as we have never had before. Incidentally, we shall do more for the rest of the world than if we study the theories of Herbert Spencer or the economic dreams of the sages. The ideals of 2000 yr. ago and the ethics of by-gone ages do not fit the situation. Let us do the thing that lies before us without hindrance from any man or nation. Let us talk what we believe. No man can tell us to stop today in these United States. The war is over!

ADDRESS OF COL. CHAUNCEY B. BAKER

AT the risk of boring you, I am going back just a little into the history of the motor car in the Army. It was a long time in gaining recognition. There were reasons back of this that I perhaps would not be applauded for stating. The first automobile that saw service in the Army in an official way came along in 1903. I remember it very well. It was brought out in exhibition at one of the annual encampments we were just commencing to have in those days and a distinguished officer was to catch a train in it at a station not so very many miles away. He started, but did not get the train until the next day.

That little thing queered the automobile game with all those who witnessed the trial. I am citing this merely to show you how very young you all are. Little was done in that way for a year or two, but in 1906 the first unit of the Army was equipped with automobile service. This happened to be the headquarters of the army of pacification that went to Havana in the autumn of 1906.

In those days great armies did not go abroad as they have done recently, and six automobiles were enough to equip the headquarters of that small body of troops. They were of various makes, and were very effective, lasting to the end, the entire 2½ yr. that we occupied that country. This will give you an idea of the great strides that had been made in 3 yr.

From that time on the automobile was a fixture in the Army so far as it was possible to induce the Congress to furnish funds. That was not easy. I had some experience in that line myself. The first motor truck to be used in the Army was purchased in June, 1907. It was sent to one of the depots and was so frequently out of repair that it was not looked upon with great favor. The next year one or two more were procured. It was not until 1912, however, that those high in authority became convinced that the motor truck could really take the place of the Army mule. From that time on the movement was very rapid. In 1912 a run of motor trucks was made through a very difficult part of our country and they all came through the test, though some of them had had more or less assistance. All of them were met at every stopping place with a multitude of spare parts, and the whole course was laid out so as to afford opportunities to repair the trucks as the parts broke, showed wear or got out of order in any way.

By the end of that fiscal year, June 30, 1913, the feeling had become very general that what we needed was the motor truck. We needed a stout one that would go where any ordinary form of transportation could go. We always had to have assistance, however, when we got close up to the troops, and it never came to be the belief of the Army men that the Army mule could actually be replaced by machines. It is not the general belief yet except in places where the troops themselves are tied to the ground, as in the trenches, or localized. When on the move across country, over fields, ditches, woods and everything else, the animal transport of the regimental organizations has still been maintained, not only in our own Army but in all other armies.

On June 30, 1913, the total number of trucks for which funds had been provided (the appropriations of Congress at that time were made so that if it stipulated money should be spent for matches it could not be spent for candles) was six in the United States and one in the Philippine Islands. However, by a strong presentation to Congress we were able to do much better from that time on, and gradually the number in use in the Army and other places increased rapidly.

At the beginning of the last Mexican trouble, when we went over the border after Villa, we had more than thirty different makes of truck in use. That may seem like a departure from any scheme of standardization but as a matter of fact it was in pursuit of standardization that this very considerable number of trucks was introduced into the military service, the object of it being to test out weaknesses and correct them; to give the makers and the engineers the opportunity to correct errors. Certainly the work that we gave those trucks on the Mexican border, and later on over the border in Mexico, disclosed whatever weak spots there were.

At the time the expedition started from the Mexican border after Villa this large number of trucks was distributed among the Army depots, military posts and large stations, with a number along the border, but there were not enough of any one kind anywhere to be organized into a body.

There was no truck organization except on paper. The draft was first put on paper in 1912 but was not accepted by the War Department until more than 3 yr. afterward. When Villa entered Columbus and shot-up the town, troops started to the south, and it was obvious at once that some means other than mule trains would have to be provided to supply the troops that were to follow him into the interior of Mexico.

This had all been foreseen by those whose business it is to watch these things, and although no funds had been appropriated arrangements had been made with manufacturers who were able to put the organizations together in the form of truck companies, which, however, were not yet recognized by the Department. They were able to furnish not only the material but the men. In those days our organization provided for no enlisted strength and for no commissioned strength, primarily because we had no trucks, but we had the paper organization and this was placed in the hands of these people.

They selected for us men who were, for the most part, particularly intelligent, those in charge being exceptionally so, and they were so prompt in turning out equipped units manned with trained men, that in one instance the officer who was to take command of a company in Chicago failed to arrive in time. Within 48 hr. or a little more the company had reached the Mexican border by rail, was immediately unloaded and was able to deliver stores to the troops in Mexico, over no roads at all, before the troops were out of rations.

One after the other the truck companies were put on the line and extended at the maximum rate, almost 500 miles below the Mexican border, over a country that was absolutely roadless for more than half of the way and mere mountain trails the rest of the way. That continued until the expedition of 10,000 men was finally brought out of Mexico.

You are all familiar with the splendid purpose of your Society and the help it gave to the Government in producing a standard truck that could be used anywhere and would find its parts wherever you could take it. In every machine shop you would find the parts to repair it, made by a sufficient number of manufacturers, so that there would never be any question as to the practicability of the Government's procuring them, and let me tell you what led incidentally to the belief that this was a necessary part of the equipment of the Army. In 1898, as you know, we were at war with Spain and the Army was equipped with mule wagons manufactured by every maker in the United States. We had a standard at that time but no manufacturer was willing to follow it. He did not have the right material for it, there was not the time to do it, and he turned out and the Government accepted the particular wagon that he was making. As a result, in the particular corps I was attached to, we received some nine or ten different makes of these wagons. We would ask for spare parts, and get them for probably nine or ten other makes of wagon. The storekeepers were not familiar with the parts themselves and good as their intentions were, they would send down the wrong ones if they did not happen to have those that we had specifically asked for. They thought something else might answer the purpose. It did not. What we did then was to go into the swamps, cut green timber and construct what we actually needed to keep our wagons in repair. It served very well and results were good, but it is not always possible to find green timber and it will not repair motor trucks.

When our truck plan was started the War Department undertook correspondence with the various manufacturers and users, and especially with your Society, and finally developed the standard truck. I do not know how to express to you our appreciation of the manner in which the members of this Society gave the very best of their lifetime of effort to the development of the best truck that they knew how to make. They came at the call of the Government and laid upon the table the most precious products of their brains, and these were welded into that standard truck.

It was claimed, in the first place, that it would not be possible to do it. Great Britain had failed, France had failed. It was maintained that there would not be sufficient time, that no truck had ever been produced in less than from 1 to 2½ yr. and that, in any event, it would be an experiment.

This is what happened: England had failed. I saw her failure myself on a visit to her factories. France had failed before making a real effort. Those two countries are not supplied with the standard machines that are used in all of our manufactories. They use a tremendously larger amount of handwork in both those countries and that is one of the reasons they not only did not succeed but did not feel the same necessity for succeeding.

The decision was made to enter upon this project late in July. By Sept. 10 the drawings for the truck were 90 per cent completed, a month later the first truck was practically completed and by Oct. 19 the first standard trucks had reached Washington and were turned over to the Secretary of War and later to the President, 69 days after the order to go ahead had been given.

By Jan. 10 the first commercial trucks were coming through and at the end of April they were coming at the rate of eighty a day. There never was a time after delivery once started that there were not trucks on the docks at the Atlantic Ocean, waiting to be sent overseas. In other words, trucks were coming through faster than it was possible to take them over.

That is what your Society—because the members of your Society are the people who are responsible for that product and you are the people who made it possible for the Government to do that thing—has done, and, as I started in to say, the Government has nothing but thanks for you for your effort, not only in this specific case but in other cases. When the history of the war comes to be written there may be some question as to who started the war, but there will never be any doubt as to who ended it. This Society and its members, not only those shown upon the service flag that hangs in front of us, but those who remained in the factories and did the work that had to be done, will have their full share of credit. When the flag of our country has been borne upon a staff tilted toward the enemy, it never yet has tilted the other way until victory has been won. In this victory you know that you have had your full share. There are those who are represented by stars on the service flag. There are members of this Society who are represented in stars of gold. May their memory shine forever. But remember that those of you who may not be represented upon that service flag may still, I beg of you, allow that we who wear the cloth may call you our next of kin.

ADDRESS BY CHARLES F. KETTERING

OUT of the great experience of the past year and a half we have gained one very interesting thing from the standpoint of the engineer. Into a great common pot has been dumped the technical information and engineering skill of all the industries. We have now at hand, as we never had before, a mass of technical information that is going to be of great avail. Next year we shall suffer from so-called reconstruction, but out of it there will come industrial development which will so far surpass the things we are familiar with, that we shall more than make up the losses we have had during the wartime period.

The demand for engineering work, the pressure of commercialism, may drag the engineer a little faster than he can step, if he does not avail himself of this information which has been so generously given. The problems that commercialism is forcing upon us will keep us running unless we grasp the situation, analyze its factors and work together. Now is the time for us to card index for quick reference all this wonderful information which we have got during the war.

Along with our aeronautical development have come a few things of scientific interest that I want to mention. One is the contribution which science has made in the way of communication. As is well known to you, our American planes are equipped with a radio telephone so that it is possible for a man in the air to communicate with his fellow pilots in the air or with headquarters on the ground. All of that development is going to be carried over from aeronautics into other things. Out of this development of radio has come a very interesting thing, as applied to our long-distance telephone work. Radio, as you know, emanates in a spherical method; that is, it gives out waves which go in all directions. It used to be necessary to have rather high-powered stations to receive and to send, but it is not now. It would be possible tonight for us to take two little card holders, place them on the table here a few feet apart, string some connecting wire between them, put a magnifying device in place and listen to talk in Arlington. We could hear the battleships along the Atlantic coast talking to each other with that much of an antenna in this room. That has been made possible by our ability to magnify the radio signals. A little device which was developed and perfected during the war time can take an insignificant signal such as we would get over these wires and multiply it, by a single step, 1000 times. Then if we cannot hear it, multiply it 1000 times again, which gives 1,000,000 amplifications or by still another thousand and we get 1,000,000,000 amplifications. The chances are we can hear it by that time but such magnification can be kept up until the radio signals become perfectly definite.

There has been another type of radio developed which is of great commercial importance known as wired wireless. This means being able to send a wireless wave along a perfectly defined path and that defined path a wire. It is quite different all the same from passing an electric current through that wire. It differs in this way: If you are sending one electric current through a wire and try to send another through, there is more or less congestion at certain parts of the wire. With this wired wireless, however, it is possible to send one, two, three, four, six or ten waves simultaneously without any interference. Long-distance telephoning is being carried on today between Washington and some of the points where they are sending four simultaneous messages. This is possible by using a special frequency to call the other end of this line whether it be St. Louis or Kansas City, without interfering with important business which may be going over those wires at the same time. Another very interesting thing about that is that there is no distortion. The voice comes through clearly and plainly, even though it is traveling along accompanied by various other messages.

That is just one angle of the development that has come during our war. The same development can be applied to matters chemical and physical, and to engineering in every line. The engineer, if he is going to take his proper place in the next 5 or 10 yr., must learn more per cubic inch than he ever learned in his life before. He has got to be entirely awake. We are going to move rapidly; we shall see marked changes in every line of industry, because in every line there has been contributed new information and new things that a year or two ago we thought were impossible, if we thought of them at all.

Air travel will be made possible through this wireless communication that we have just discussed. There is one very fine thing about air travel, and that is that we can select the kind of weather we want. If it is raining in Chicago, as it almost always is, and we don't want to come to Chicago in a rain, we can just fly above it. I am not sure that the people of Chicago know that the sun shines above them, but it does. The only difficulty with flying above the clouds is to know where you are. Up there is about as lost a place as we can get into on earth. With little radio signals dotted down the line 25 miles apart and telephone receivers at his ears, the flyer could lie down, read or do anything he wished up in his airplane and still follow his course across the country.

Interesting things have been mentioned here tonight on the commercial side of flying, and the airplane is used as a synonym for speed. I want to use it as a symbol for many other things. The reason we go by airplane is that we want to get there in a hurry. I have used a plane commercially for the last year and a half. Colonel Baker and I came from the same school; were graduated in the same year. I happen to have to go over to that university once a month to attend a meeting of the board of trustees. It is about 75 miles from where I live to the city of Columbus. I have driven over there in 95 min. because a fellow was ahead of me and pulled all the cops off the road, but if I want to go over there as a high-grade, law-abiding citizen I have to take about 3 hr. to get there; to make a 10 a. m. meeting I must leave at 7 in the morning. If I go by airplane, I can wait until 9 o'clock or later. In fact, I can go from Dayton to Columbus as quickly as another member of our board can go in a street car from the Union Depot in Columbus to the University. I can stay there until 3 o'clock and be back home at 3:30.

Such economy in speed is so fundamental that the aircraft industry will live regardless of what we think about it. We left Dayton at 11 a. m. and were in New York City at 3 p. m., 555 miles in 4 hr. As they have no regular place to land in New York City, we went 25 miles the other side of it to get down. We had sent telegrams to New York City, one ordering a taxicab to meet us at Mineola, another for rooms at the hotel and another for some theater tickets. We landed at Mineola and went into town, got to the hotel, cleaned up a little, took a nap, had dinner, went to a theater and were back in our rooms at 11 p. m. just 12 hr. after we left Dayton. The shortest time in which we could have made the trip by train is 18½ hr. That is a practical application of what can be done if conditions are right. There were a few places on that trip where if we had been compelled to come down, we would have had to juggle around a little bit, but then we would have come down, no question about that.

When we get this radio-marking across the country, it will be possible to take an airplane equipped with some new compass devices we already have and some other little trinkets that were developed during the war, put it on a course from Chicago to Dayton, and turn the flying of it over to the compass, which will do it better than we could anyway. I will guarantee that without touching the machine it will not miss the city of Dayton by 10 miles. We have done some things along that line, and since they cannot be denied, the sort of thing we hear about aircraft being unstable and fickle sounds ridiculous. We have flown from Dayton to Indianapolis without touching the controls, missing the center of the city by less than 1 mile; also from Dayton to Columbus without touching the controls, missing the city by less than ½ mile. There is no reason why we could not fly to Kansas City if we had to.

I am talking of the aircraft business because it is typical. The automobile, the tractor, the truck, every division of automotive engineering that has had or promises to have development equally great, has struggled with problems of equal importance. We have before us fuel problems. We have a lot of problems that must be solved by coupling together all the engineering knowledge available and directing it along a particular line. Nobody is satisfied with the way an automobile runs today, because of the fuel supplied.

It is pretty definitely settled that we are going to accept just exactly what we get in the way of fuels, and I would say in defense of the oil companies that they are giving us the best they can. We can quarrel about the fuel all we want to, or design engines and equipment that will handle the fuel we get. When we have the problem solved we will wonder why we ever worried about it. The man who has wire fences on his farm is not troubled about the shortage of timber for fence rails. We shall not kick about the quality of our fuel when the engines are once developed that will handle any kind of fuel. It is no longer a problem; it is right in front of us today, with a dozen other things that we have got to do.

New materials have been brought out during the war that are going to affect all sorts of design in just exactly the way that high-speed steel affected the machinery industry. The introduction of this new steel into the cutting tools of our machinery has entirely revolutionized machine design. I can remember very distinctly when, not over 7 yr. ago, a machinery builder came into one of our plants, and, because of the failure of one of the tools to do what we had expected, said to me "If you take that fool high-speed steel out of there and put in ordinary steel you will have no trouble with the machine." That was absolutely true, but who wants to run his machines at half speed? That is what his suggestion meant, and the machinery people, after trying to convince us that we were running their machinery too fast, found out that neither of us could slow down.

It is well to remember that when an industry or a nation gets worked up to a certain speed, it is an awful thing to slow it down. We have learned things. We have gained the ability to do the trick of going ahead in the last year and a half, and nothing will slow us down. What is going to happen is that the fellow who believes we shall now slow down will himself in the end speed up to keep along with the procession.

PRODUCTION OF HELIUM

AT a meeting held at the Chemists' Club, New York City, Jan. 17, Dr. Frederick G. Cottrell, chief metallurgist of the Bureau of Mines, Department of the Interior, was presented with the Perkin medal for distinguished service in chemical research. In accepting the honor, he outlined certain investigations now being undertaken by the metallurgical division of the Bureau, which, if successful, will result in a real revolution in the fundamental industries of the country.

Dr. Cottrell, in telling of this important work, said in part:

"When, at the suggestion of Sir William Ramsay, the British Admiralty first studied the possible use of helium for balloon purposes they felt that the expense of production would be prohibitive; first, on account of the great scarcity of the element and the very great dilution in which it is found in the atmosphere (1 volume in 250,000) and in other gases; and, second, because of the expense of the processes of separation then known to the Admiralty.

"When this information came to the Bureau of Mines it was remembered that some of the natural gases of Kansas had been found by Dr. H. P. Cady of the University of Kansas to have over 1 per cent of helium in them. The separation of helium from these gases could best be accomplished by the same general processes of liquefaction and distillation as are used to separate air into nitrogen and oxygen for industrial purposes.

"It so happened that the metallurgical division of the Bureau of Mines had been making a study of these processes in the hope of finding a way to cheapen the production of oxygen from the air sufficiently to allow its general use in metallurgical furnaces and other large-scale chemical and industrial operations. If this were possible it would work a real revolution in these fundamental industries. Take, for instance, the smelting industry alone. We now concentrate everything that goes into the furnace, coke, ore, fluxes, etc., except the oxygen of the air, which we add with four times its volume of inert nitrogen and thus undo much of the effect of the concentration of the other constituents. If we could use pure oxygen, or more concentrated air, a great saving would be effected, and we could do in combustion furnaces much that is now possible only in the electric furnace.

"One of the processes which the Bureau felt had much promise in this direction had not received any large-scale development, but the facts were called to the attention of the Army and Navy, which jointly appropriated first $100,000 and afterward further sums, now aggregating over $1,000,000, for trying out the project along the line not only of the new process but of the older and better known processes as well; entrusting the general direction of the work to the Bureau of Mines.

"The plants using the older processes are already producing helium in large quantities, and the one working on the new basis which it is hoped will prove several times more economical is about to have its practical production test. If it fulfills anticipations, its significance will be far wider than relates to the production of helium, for it will open the possibility of oxygen in quantity at costs undreamed of by most chemists and metallurgists."

TO EXPEND $500,000,000 FOR ROAD BUILDING

AT a recent conference of representatives of the highway departments of twenty-seven Eastern, Southern and Middle Western states, the Secretary of Agriculture announced that the department would hereafter give every possible help in expediting resumption and progress of highway building under the Federal Aid Road Act. A canvass of the representatives in attendance indicated that if conditions were favorable in the next 18 months, approximately $500,000,000 will be expended for road building from Federal, State and local funds. It is estimated that this work will employ more than 100,000 men in active road work in addition to those engaged in the production and furnishing of material. This figure does not include any increase in the number of men engaged in building road machinery.

LAW FOR HEADLAMP REGULATION PROPOSED

THE committee on lighting legislation of the Illuminating Engineering Society has issued a set of proposed regulations designed for incorporation in the laws of the various states in regard to headlamps on motor vehicles. The regulations are based upon proposals of the technical committee on automobile headlighting specifications of that Society and relate only to what are known as headlamps (or headlights) and spotlights. The aim of the committee has been to set forth clearly the intent of the regulations, it being assumed that the phraseology will be altered where necessary to conform with legal requirements to insure the proper administration and enforcement of legislation. The proposed regulations follow:

(1) Every motor vehicle operated or driven on the public highways of the state at any time when there is not sufficient light to render clearly discernible a person, vehicle or other substantial object on the highway at a distance of 200 ft. ahead, shall be provided with a headlamp or headlamps of sufficient power and so adjusted and operated as to enable the driver to proceed with safety to himself and to other users of the highways under all ordinary conditions of road and weather. All motor vehicles, excepting motorcycles, shall display at least two headlamps of approximately equal candlepower mounted on opposite sides, which will on a level road render clearly discernible a person, vehicle or other substantial object 200 ft. directly ahead of the motor vehicle and will at the same time render clearly discernible an object 100 ft. ahead and 7 ft. to the right of the axis of the motor vehicle; excepting that for motor trucks which are so governed or mechanically constructed or controlled that they cannot exceed a speed of 15 miles per hr., the headlamps must render clearly discernible a person, vehicle or other substantial object 50 ft. directly ahead of the motor vehicle and also render clearly discernible a person, vehicle or other substantial object 25 ft. ahead and 7 ft. to the right of the axis of the motor vehicle.

(2) Motorcycles shall be provided with at least one headlamp which will on a level road render clearly discernible a person, vehicle or other substantial object 100 ft. ahead.

(3) The headlamp or headlamps on motor vehicles shall be so arranged, adjusted and operated as to avoid dangerous glare or dazzle, and so that no dangerous or dazzling light, projected to the left of the axis of the motor vehicle, is cast in the eyes of a driver of a vehicle approaching in the opposite direction.

(4) Adjustable headlamps in the control of the driver may be used subject to the restrictions in sections 1, 2 and 3. Spotlights may be used subject to the restrictions as to glare or dazzle in section 3.

(5) Any person may submit to the Secretary of State[1] for approval types of headlighting equipment, together with an application that such devices be tested as to conformity with the provisions of this act. Such applicant shall pay to the Secretary of State a fee to be fixed by the Secretary of State covering a reasonable cost of such test. The Secretary of State shall be authorized to issue certificates of approval of such types of headlighting equipment as have been shown by exact scientific and laboratory tests under uniform specifications to conform with the requirements of this act when used in accordance with the instructions in section 10. The reports of all tests shall be accessible to the public. The Secretary of State shall publish and disseminate a list of approved types of headlighting equipment.

(6) For the purpose of preparing specifications and instructions for the headlamp tests, the Secretary of State shall be authorized to establish a board of not less than three experts not commercially interested directly or indirectly in any headlighting control apparatus, who shall serve without pay and who are qualified to make in terms of measurable quantities an interpretation of the requirements of this act; or he may adopt specifications and instructions prepared and recommended by a recognized engineering society of national scope specializing in the subject of light and illumination. The uniform specifications and instructions so established shall be promulgated by the Secretary of State and shall relate to

(a) Tests of headlights on motor vehicles as made in public testing stations provided for in section 7. This specification shall include a numerical interpretation of the illumination required for discernibility of a person, vehicle or substantial object at distances ahead of the motor vehicle set forth in sections 1 and 2, and also numerical interpretations of the limits of dangerous glare and dazzle set forth in section 3.

(b) Laboratory tests of headlighting devices for the purpose of determining their acceptability under section 5. These specifications shall set forth the manner in which the tests are to be made and the numerical limits imposed on approved devices with reference to the power of the light produced and the limitation of glare to conform to the requirements of sections 1 and 3.

(7) The Secretary of State shall be authorized to license individuals[2] who in his judgment are properly equipped and otherwise qualified to test and adjust the headlamps of motor vehicles for conformity to the law as interpreted by the specifications provided for in subdivision (a) of section 6.

(8) Police officers shall be empowered to issue to such drivers as in their judgment violate any of the provisions of this act, summons requiring the person charged with such violation to appear at a licensed test station as provided for in section 7, within a term of —— days[3] for a test of the headlamps. The Secretary of State shall authorize such licensees to collect a fee,[3] not to exceed ——— dollars, for such services. The licensee shall keep a record of all tests made by him. The license numbers of such motor vehicles and the results of the test shall be reported to the Secretary of State[1] and to the proper municipal authorities, and the results of the test shall also be reported to the person charged with violaton of the act. The results of such tests shall be presumptive evidence in any prosecution for violation of the provisions of this act. If any person so served with summons does not submit to the test as required in this section, the testimony of the police officer serving same shall be presumptive evidence of such violation. A person charged with violation of the act shall have the right of appeal to the Secretary of State from the findings of such tests.

(9) The Secretary of State shall be authorized to send inspectors of motor vehicle lamps upon the highways at night for the purpose of verifying by measurement conformity to the provisions of this act.

(10) No headlamp or headlamp control device shall be sold by a dealer that is not accompanied by a printed sheet of instructions describing the device in detail, its method of mounting and adjustment, type and candlepower of lamps to be used and any other adjustments that may be necessary to insure its conformity with the requirements of this act.

(11) On and after ———[4] no type of headlamp equipment shall be sold that has not been officially approved by the Secretary of State.

[1] It is assumed the title of any other proper administrative official or board will be substituted throughout for that of the Secretary of State, and that the titles of proper municipal authorities will be inserted in section 8.

[2] The desirability of licensing properly qualified garage mechanics is suggested in this connection.

[3] It is suggested that the fee for a test, made in response to a summons, at a public test station, should not exceed $1, and that the test in response to such a summons should be made within a term of two days.

[4] It is suggested that the date be fixed at one year from the date this act becomes effective.

THE COMMERCIAL ZEPPELIN

AT last man has ascended higher than the lark and flown faster than the eagle and farther than the mightiest bird of prey. Small wonder then that he should consider the flight across the Atlantic by either the airplane or the Zeppelin as nothing but a question of time.

As a matter of fact man does not doubt that eventually not only the Atlantic, the Pacific and the seven seas, but even the globe itself will be aerially transnavigated. His only concern is how soon these feats will be accomplished facts.

Several preparations, but only one real attempt, to fly across the Atlantic have already been made. The first effort to cross the ocean from America to Europe by air was made by Walter Wellman and a crew of five men in the dirigible America on Oct. 15, 1910. The airship measured 228 ft. in length and 52 ft. in diameter, with a lifting capacity of 12 tons. The envelope carrying the gas weighed approximately 2 tons. Attached to the bag was a car 156 ft. long. The 9000 lb. of gasoline necessary for the trip were stored under the floor of the car. The America carried three 80-hp. gasoline engines, one of which was a donkey, the two others being used to drive the propellers. Beneath the car hung a 27-ft. lifeboat that was to be used in case they had to abandon the airship. A 330-ft. equilibrator, consisting of a long steel cable on which were strung thirty spool-like steel tanks each carrying 75 lb. of gasoline and forty wooden blocks, trailed from the cabin. The blocks were about 20 in. long.

The object of the equilibrator was to eliminate ballast. It was intended that the balloon should sail along at a height of about 200 ft.; if it settled close to the water the wooden blocks and the tanks would float on the water and relieve it of some of its weight. The America was also equipped with sextants, compasses and other instruments for locating its position, the same as an ocean liner.

They left Atlantic City in a dead calm and were towed out to sea by a motor boat. Three days later, on Oct. 18, after many vicissitudes, the engines broke down and the huge gas bag was at the mercy of the winds. Wellman and his crew were picked up by the steamer Trent, 375 miles east of Cape Hatteras. The dirigible had been carried out of its course because of insufficient power to navigate against the winds and had to be abandoned, a total loss.

A year later, financed by the Chamber of Commerce of Akron, Ohio, and one of the large rubber companies, a balloon called the Akron, 268 ft. long and 47 ft. in diameter, with a gas capacity of 350,000 cu. ft., was built to be flown across the Atlantic by Melvin Vaniman. It had two 105-hp. engines. Unfortunately, on July 2, 1912, while making a trial flight, the balloon took fire and exploded, killing Melvin Vaniman and the four members of his crew. The disaster put an end to building dirigibles in this country for transatlantic flight.

The preparation for another attempt to cross the Atlantic was made by Glenn H. Curtiss through the generosity of Rodman Wanamaker, who financed the building of the flying boat America. Owing to the breaking out of the war this project was abandoned.

Neither of these two American-built lighter-than-air ships could be compared in size, engine power, lifting capacity or flying radius with the dirigibles constructed by the German Government and people under the direction of Count Ferdinand von Zeppelin. Indeed his first airship, constructed in 1900, measured 410 ft. and contained 400,000 cu. ft. of hydrogen, whereas the super-Zeppelins were many times larger than either the Wellman or Vaniman airship.

Since the Zeppelin, like all airships, is buoyed up by hydrogen gas—which weighs 1.1 lb. per 200 cu. ft. as compared with 16 lb. which the same amount of air weighs—the dirigible is sent up by the simple expedient of increasing the volume of gas in the envelopes until the vessel rises. This was done by releasing the gas from storage tanks into the gas bags. To head the nose up, air was kept in certain of the rear bags, thus making the tail heavier than the forward part, which naturally rose first. Steering was done by a rudder or the engines or both, and the airship was kept on an even keel by the use of lateral planes. The airship could be brought down by forcing the gas out of the bags into the gas tanks, thus decreasing the volume, and by increasing the air in various compartments.

This airship had a flying radius of 800 miles, could climb to 12,000 ft., could carry a useful load of 30 tons and remain in the air for 50 hr.

Exact figures on the cost of Zeppelins are not available. W. L. Marsh, in the British publication *Aeronautics*, gives $500,000 as the estimated cost of a super-dirigible of 60 tons having a lift of 38 tons. This high cost is due, among other things, to the enormous building in which the airship must be constructed, for it should be borne in mind that one of these dinosaurs of the air extends its bulk along the ground farther than the Woolworth Building towers in the air. Indeed, it could not descend in an ordinary city street because of its bulk, and if it did it would extend nearly four city blocks of frontage. Moreover, the plant necessary to generate the sufficient hydrogen gas to inflate a bag of 2,000,000-cu. ft. capacity would cost $50,000 alone. The amount of aluminum in the L-49, forced to land in France in the spring of 1918, would make a footbridge over the East River as long as the famous Brooklyn Bridge.

To land and house such an elusive and buoyant monster requires many winches and some 200 men. Even then some have been known to run away.

The greatest dangers to the airship are wind, storms and fire. Of these the last is the most to be feared because hydrogen gas is so highly explosive.

Perhaps of all the revolutionary scientific developments of the great war—especially in the field of chemistry—the one that may perform the greatest service to mankind has been taken by the Bureau of Mines to produce helium, the non-inflammable gas which has 92 per cent of the lifting power of hydrogen, in sufficient quantities to be used in floating airships.

A noninflammable gas with such a lifting capacity as helium has been the dream of the aeronaut and the dirigible engineer. The greatest danger to people riding in dirigibles is the possibility of heat expanding and exploding the hydrogen gas. One of the first airships to experience this fate simply passed through a cloud into the hot sun, whose rays expanded and exploded the gas. The substitution of helium entirely eliminates that danger and makes it possible to carry heating devices for the comfort of passengers in high altitudes.

On Dec. 12, an interesting experiment of launching a plane from a dirigible was conducted at Rockaway Beach, N. Y. The dirigible rose about 100 ft. above the sand field near Fort Tilden. An airplane was attached to the roof. After discharging ballast and starting the engine the dirigible ascended to 3000 ft. and released the airplane, which dived about 1000 ft. and then flew off to Mineola.

This experiment is cited only as an indication of what the possibilities are of combining the airplane with the dirigible in landing mail or express from dirigibles crossing the Atlantic. That airplanes weighing only 1000 lb., with a flying radius of 600 miles and making 150 miles per hr., could be launched from super-dirigibles 500 miles from the journey's end may not be a remote possibility if airships are to be constructed with 10,000.000 cu. ft. of gas, with a 60 per cent lift for crew, fuel, freight, and so on.

Evan J. David, in *Saturday Evening Post*.

Vol. IV April, 1919 No. 4

More Efficient Utilization of Fuel

By Charles F. Kettering[1] (*Member*)

Annual Meeting Paper *Illustrated with* Photographs and Diagrams

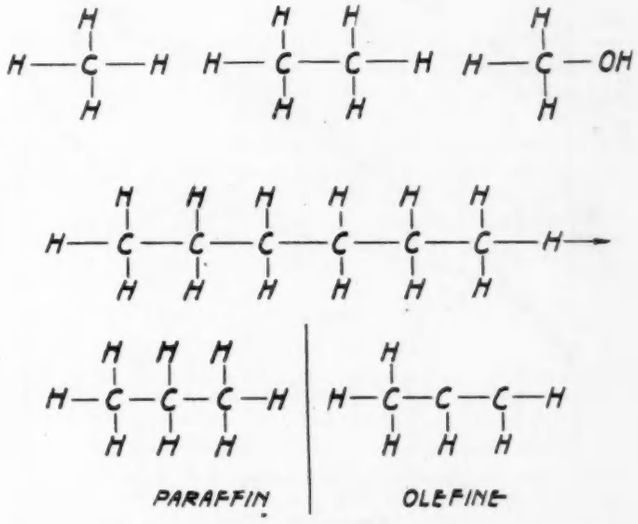
As far as the automotive engineer is concerned, there are two problems involved in the fuel situation, each of which is of great importance. These have to do with the application of fuel to an internal-combustion engine. One is getting the fuel into the engine, and the other is burning it after it gets in.

To get the fuel into the engine, innumerable devices have been constructed and given consideration, and yet I think we all recognize that the results from these have been disappointing, because they did not solve the problem that really needed solving; namely, what happens inside of the cylinder. Having recognized this condition of practically complete ignorance as regards what goes on within the cylinder of an engine during operation, we started to see what we could find out about it. Naturally it is a little difficult to sit around in a cylinder while it is in operation and tell just what happens in there, so we had to devise ways and means of staying outside and still telling what was going on inside. In doing so we had to build some new instruments, and we had to do a lot of theorizing. The result is that some of the things I am going to tell you may not be so, but then it is not my fault if they are not.

In discussing the question of fuels I think it would be well to go back a little. Our present idea of fuel, as you know, is that a satisfactory fuel must have a certain gravity. I want to go into the fuel situation a little more deeply than merely determining its uses according to its gravity. It has been a general observation that as you lower the gravity of a fuel, such as the present commercial fuels on the market, even though you get the fuel properly distributed, you have to lower the compression of the engine because of the knock which results. This knock is the kerosene knock, preignition, pinging, or whatever it is called. To make my subsequent discussion somewhat more intelligible I want to first discuss briefly the construction of a fuel, its relation to gravity, etc., and then what happens when we try to burn it.

Chemical Composition

As you know, all of our fuels are hydrocarbons. I think we have all studjed the subject enough to know that a hydrocarbon is a very uncertain and miscellaneous sort of an individual, consisting of varying combinations of carbon and hydrogen. If we start out with carbon we see that it is a four-valent element, that is, it has the ability to combine with four uni-valent atoms, such as hydrogen. The simplest hydrocarbon combination is that in which four hydrogen atoms are combined with a single carbon atom, the bonds uniting the hydrogens with the carbons being as indicated. This compound is methane, which is a large constituent of natural gas. The chemistry of the hydrocarbons would not be very difficult if it always worked out as in the case of methane; that is, if each carbon atom always united with four hydrogen atoms, or four uni-valent atoms. But the carbon also has the ability to combine with itself, that is, to satisfy certain of its chemical bonds by combining with other carbon atoms. It is quite possible to have another compound in which two carbon atoms are united, each in addition having certain hydrogen atoms united with it. The first compound referred to above is said to have the formula CH_4 and the second the formula C_2H_6; but I will show you that such a formula really means nothing. If we insert another carbon atom between the other two and add the two hydrogen atoms to it, you get a third hydrocarbon, the formula for which is C_3H_8. In other words, if you take a series like this and add a carbon atom each time, with its corresponding hydrogen atoms, you get a general formula which may be expressed thus: C_nH_{2n+2} In this series the compounds get very long, and increase



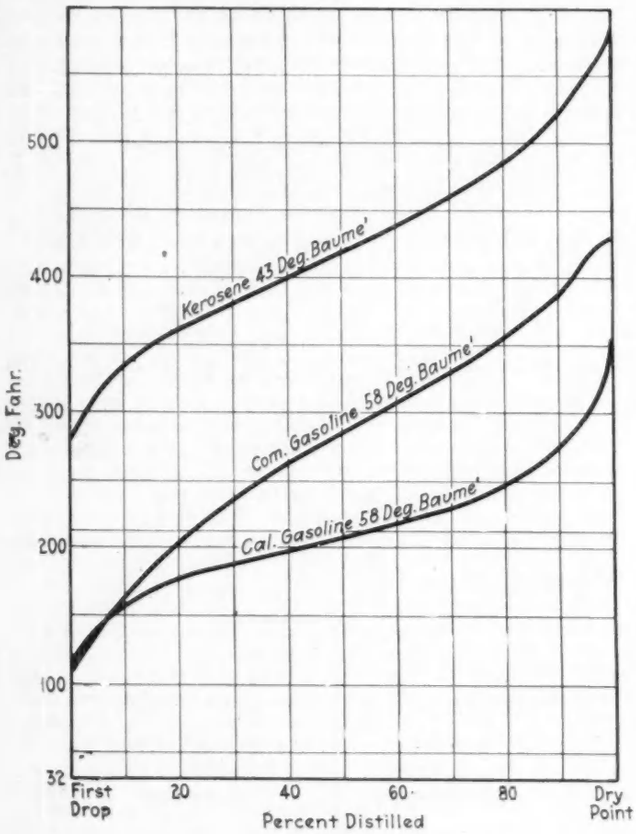
Some of the Simpler Hydrocarbon Compounds and What Happens when a Complex One Is Cracked

correspondingly in gravity. This increase in gravity gives a corresponding increase in the boiling point, and I would like to say here that boiling is only a simple way of measuring the weight of a molecule.

We have heard considerable talk about cracking. Now supposing I take one of these big molecule compounds and break it in two, I will get two smaller compounds. You might have to throw away some of the carbon because if you break such a compound in two you will not have enough hydrogen for the end carbons. This does not necessarily follow, however, for it is possible to have

[1]President, Dayton Engineering Laboratories Co., Dayton, Ohio.

a compound which apparently has not enough hydrogen in it. If we take one of these heavier hydrocarbons, for instance, and crack it in two we have as one compound a paraffin which is analogous to the compounds shown above, and as the remainder another compound which is obviously different from those called paraffins; such compounds being given the general name of olefins. The olefins have a general chemical formula of C_nH_{2n}. The cracking process then consists in breaking up these larger molecules into smaller ones. In breaking up hydrocarbons you put them in a big drum, hit them and hammer around and finally they get sore, as it were, and say, "What's the use? We might as well break up." That is exactly the way you get an increased volume of gasoline. There is, of course, some loss in throwing away carbon. I want you to keep this in mind, however: that, if heating under pressure and high temperature produces disintegration of these molecules in a cracking still, the same identical thing may happen when you maltreat the fuel



DISTILLATION CURVES OF VARIOUS INTERNAL-COMBUSTION ENGINE FUELS

in a gas engine. I want you to keep this specifically in mind because heat and pressure have about the same effect regardless of where they happen to be, in a gas engine or in some other place.

I want to impress upon you another very important fact. If you take the heat of a pound of carbon and the heat of a pound of hydrogen, you will find, if you burn the gas CH_4 mentioned above, that you will not get the same amount of heat from this gas as you would expect if you added up the heat contained in the corresponding amounts of carbon and of hydrogen. It will always be somewhat less. This apparent loss in heat value is a result of what is known as energy of combination and enters largely into the study of chemical compoounds. I want to impress on you the fact that each of these compounds has a certain heat value which is always less than the total heat value of an equal quantity of carbon and hydrogen in an uncombined state.

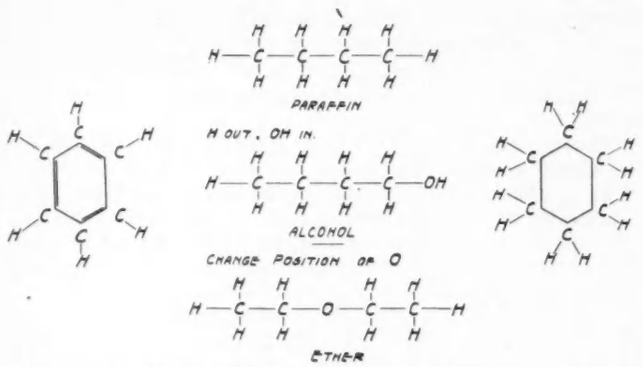
SPECIFIC GRAVITY OF FUELS

The question of gravity and the size of a molecule is a very interesting thing. If we start with the simplest compound of the paraffin series, CH_4, and add carbon and hydrogen atoms to it, one of carbon and two of hydrogen at a time, we find that the first few compounds are normally a very light gas and extremely difficult to liquefy. As we come down the line, we find that the compounds would become normally liquid, and finally solid, in form. Carbon has an atomic weight of twelve and hydrogen of one, so that CH_4 has a weight of sixteen. As these compounds increase by CH_2 each time, which means an increase of fourteen in the molecular weights for each compound, it is quite obvious that the molecular weights will mount up rather fast. It is easy to see that these are actually physical things. There has always been one trouble with all of our theoretical work. We take up this molecule as though it were simply something to think about and to talk about. But these are real physical things and the combination and decomposition of these things are real physical facts. I think that if we all could get the point of view that this is not complex at all, and we could get somebody to write a chemistry that would make it appear simple instead of complex, we would all get interested in this and be able to do a lot of good by actually studying the fundamental phenomena.

As I mentioned before, the more carbon atoms you get into the compounds, the heavier the fuel becomes. It was for this reason that we, a long time ago, began to measure our fuel by hydrometers. If it measured 72 deg. it was fine. Finally it began to go down and down, and we tried to force upon our oil people the idea that gravity had something to do with a fuel's desirability. Now gravity has not a thing to do with it.

Suppose we started a food law in this country that we had to sell potatoes not by the bushel or by the pound, but that there had to be so many potatoes to the bushel, and that they had to have an average weight per bushel. This is actually what we asked the fuel people to do. Suppose then the food inspector comes around and examines a bushel of potatoes. He goes through it and counts the potatoes and says "There are not enough"; so he takes out one big potato and puts in a couple of small ones and the potatoes are O K'd by him. Then, after the potatoes are sold, they are placed in a pan and put into an oven to bake. And if you leave them in there for an hour, the little potatoes are burned to a crisp and the big ones are not cooked through. Exactly the same thing happens with fuel. There is no difference whatsoever. The average of your fuel may be all right, but that does not mean that you have anything like a good fuel.

Distillation curves have come to be a measure of fuel suitability. They are of a great deal more importance than its gravity. I have had charts showing certain distillation curves prepared. In the chart there is shown a kerosene curve. This kerosene had a gravity of 43 deg, and it started to distill off at about 275 deg. fahr., the percentage evaporated increasing with continued heating and a rising temperature until it finally goes dry at 600 deg. fahr. This is a characteristic curve. This chart also shows commercial gasoline having a gravity of about 58. It shows, in addition, a very interesting and signifi-



TYPICAL "RING" AND "CHAIN" HYDROCARBON COMPOUNDS AND THE CHANGES PRODUCED BY VARYING THE RELATIVE RELATIONS OF THE DIFFERENT ATOMS

cant fact. When the curve of a California gasoline of 58 gravity is compared with the curve of this other gasoline of 58 gravity, it is seen that the California gasoline has a considerably flatter curve. The reason for this I will show later. We all know that there have been developed in California many wonderful kerosene carbureters which were sent to us here in the East, but which, when put on our engines, failed signally to live up to the claims made for them. This is easily explained. The fact is, California kerosene is often a great deal better than our gasoline, so far as carburetion is concerned.

BENZOL AND ALCOHOL AS FUEL

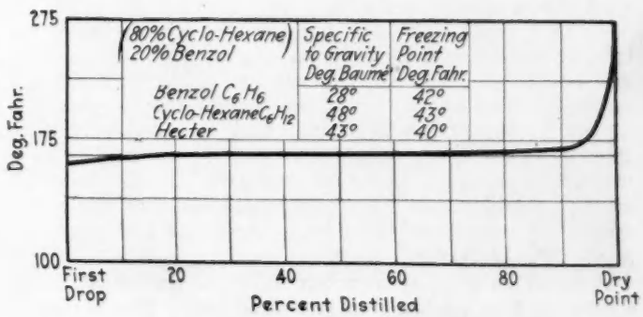
In addition to the types of hydrogen and carbon compounds already discussed, which, because of the arrangement of the atoms therein, are called "chain" compounds, there are certain other hydrogen and carbon combinations called "ring" compounds. One of the simplest and probably the best known of these is benzol. In this there are six carbon atoms, with three single and three double bonds connecting them, each carbon atom having a single hydrogen atom attached to it. The formula for this compound is C_6H_6. As you no doubt remember, when Mr. Crane was discussing his paper on "Possible Effect of Aircraft Engine Development on Automobile Practice" he mentioned the fact that by the addition of a certain amount of benzol to a fuel, certain very interesting results are obtained. That does not of itself mean that benzol will necessarily make a good fuel, because there happen to be other considerations involved. If you run benzol on full load it gives satisfactory results. It is so high in carbon as compared with the amount of hydrogen that if you do not run it on full load very copious productions of carbon in the engine result. This carbon, however, is quite different in character from the carbon which results from the burning of kerosene. It is a fine, fluffy or flaky deposit, not at all gummy or sticky like a kerosene carbon deposit and is blown out readily in the engine exhaust. It does carbonize the spark-plugs badly, however, and will interfere seriously with the running of the engine.

There is an interesting thing about this type of fuel, and this is that all of the "potatoes" are exactly the same size. The benzol distillation curve represents a mixture of certain of these uniformly sized "potatoes," and you can see what happens. After you get up to a certain temperature, the fuel begins to distill off and practically all of the fuel goes off at that temperature. In other words, all the molecules weigh the same and they all get out at the same time. At the very end of the distillation curve the end point goes up rapidly. A fuel having this characteristic may or may not have desirable characteristics from the standpoint of distribution, but its functioning after it once gets into the engine may be of an entirely different order from the functioning of another fuel having a corresponding gravity. This fuel may be of much lower gravity than another type and yet function very much better under combustion conditions within a cylinder. The gravity of a fuel has absolutely nothing to do with what the fuel really is, or how it performs in service. The main point I want to get to you is that the fuel proposition is, so far as future engine design is concerned, practically a question of chemical construction and make-up, together with energy of combination that exists within the fuel itself.

There is still another illustration of the fact that the chemical formula does not mean anything. If we take benzol and break the double bonds existing in the benzol ring and add a hydrogen atom to each carbon atom we will get a compound having the formula C_6H_{12}, which represents a certain thing and a certain specific gravity.

We have heard a great deal of discussion about alcohol. The formula is $C_nH_{2n+2}O$; but that is not a very good way to write it. It is better to write it in the manner illustrated herewith. If you take a "chain" compound of the structure shown there and trade the hydrogen atom for a hydrogen and oxygen atom, you get a compound having the structure shown there as alcohol. That hydrogen substitution is the only difference between paraffins and alcohol. The paraffin compound has a certain gravity and will function in a certain way. The alcohol corresponding thereto has a certain gravity and functions in a certain way. The fuel value of these two compounds following the substitution of OH for H is quite different. The alcohol does not burn the same way or act the same way. You have the same amount of carbon in each and practically the same amount of hydrogen, but you have an oxygen atom hooked up in connection with one of the hydrogen atoms. Investigation will show that it takes practically one-half the total amount of heat available in the fuel to get an oxygen atom into the compound, and yet consideration of the actual atoms within the compound would tend to show that it should have about the same amount of heat as before the change occurred.

Suppose we take the alcohol illustrated and use exactly the same atoms, but simply shift the arrangement of them around a little, so that the oxygen is connected to two carbon atoms and not directly to any hydrogen atoms as shown; in this case we have the hydrogen atoms in the same place and the carbon atoms in the same place, except with relation to the oxygen atom, but we now have ether instead of alcohol. The two have exactly the same composition so far as the number of atoms is concerned; so that the chemical formula, if merely written out,

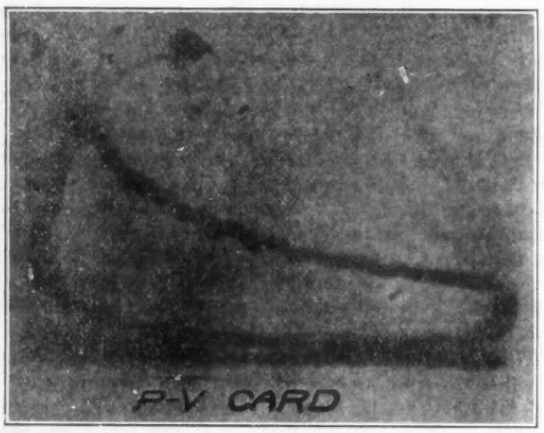


DISTILLATION CURVE OF BENZOL

would be exactly the same thing, $C_4H_{10}O$. If you bought alcohol according to chemical formula, you might easily make a mistake and put yourself permanently to sleep. Also, performance in an engine is entirely different. The gravity of these two is practically the same, but the boiling point of the ether shown is 95 deg. fahr., while that of the alcohol shown is about 243 deg. fahr. Inasmuch as they have exactly the same chemical formula, it is obviously of great importance to know something about their structure and make-up, to determine performance as fuel. If we refine our shale oils, and are going to make the right kind of engine to run on such oils, we have to know what kind of business relationship the atoms have gone into with each other before we can handle the oils properly.

Cylinder Knocks

I have mentioned energy of combination because to us it has proved very, very interesting, inasmuch as it apparently affects fuel action very directly. As I said before, as fuels of lower gravity came into use it became necessary to lower compressions. The general idea has been that this lowering of compressions has been necessary because of preignition. To study this problem we developed an indicator which gave us a new but very satisfactory type of indicator card. This indicator is different in that it gives pressure-time indications and not pressure-volume. As a result of our work with this indicator, we discovered that the knock which comes from



A Typical Pressure-Volume Card Secured from an Internal-Combustion Engine

kerosene is an entirely different thing from actual preignition. We have made hundreds of indicator diagrams or cards with this instrument and each of them is very different from the usual pressure-volume card secured with the ordinary indicator.

A card made with our indicator is also shown illustrating the normal burn in an engine cylinder, without any evidence of a knock. As you can see from this card, pressures begin to go up at the instant the compression stroke of the piston is started and increase uniformly until ignition, after which pressures go up rapidly to a maximum and then taper off gradually during the work stroke of the piston. The difference between the cards made on these two types of indicator is quite obvious and needs no explanation.

Another card made with our indicator and illustrating a case of true preignition is reproduced. The kerosene knock occurs in a region of from 10 deg. after ignition to 25 deg. past top center on the down stroke. In one card shown, the knock occurs fairly early in the combustion stroke, while in another its occurs at approximately 25 deg. after top center and on the down stroke of the piston.

These cards proved tremendously interesting to us and we began to study the knock to see what it is and why it is. In the course of our study we have been theorizing and reached the following conclusion. If you take a complex molecule and start to burn it, it will not burn by a single step from the carbon and hydrogen in it to carbon dioxide and water, but as it starts to break down it may be decomposed into a variety of compounds. If during this burning you should happen to liberate, for an instant, as intermediate products of combustion, some compounds of an extremely explosive or detonatable nature, you would, upon explosion of these compounds, get such a sudden rise in pressure as is indicated in the cards shown. Now the compounds which you form, if these big molecules do break down in this way, will differ, depending upon the temperature and pressure conditions at the time combustion takes place. That is, the type of compounds which are formed will vary with the compression, explosion pressures and the temperatures which exist in the cylinders.

In studying the conditions existent within the cylinder during knocking we endeavored to get an actual view of conditions within the cylinder at the time the knocking took place. To do this we put a window in the cylinder and pointed a spectroscope at this window. In this way we were able to reach some rather definite ideas as to the substances or compounds actually present and causing the knock. As a result of these observations we came to the conclusion that the compound which caused the trouble is acetylene. I will admit that this is one of the things that we have only theorized about so far and that we do not know now that this is really true.

What takes place within a cylinder when the knock occurs may readily be in accordance with my previously mentioned conception. You have all seen the grains of powder used in big guns. It comes in little sticks with perforations through them. Now you can take one of these sticks and light it with a match and hold it in your hand as it burns and it is perfectly harmless. But if you stuff that powder into an iron pipe and screw the end on it and light it, and then get away in time, you would witness quite a different reaction. The reason is that when you vary the pressure and temperature conditions you change the entire nature of the burn. In other words, in the first case you are simply burning the stick of powder as you would any other inflammable hydrocarbon, while in the second case you are releasing its energy of combination in a very short space of time. The resulting variation in the chemical reaction which takes place causes the sudden building up of pressure that we call an explosion.

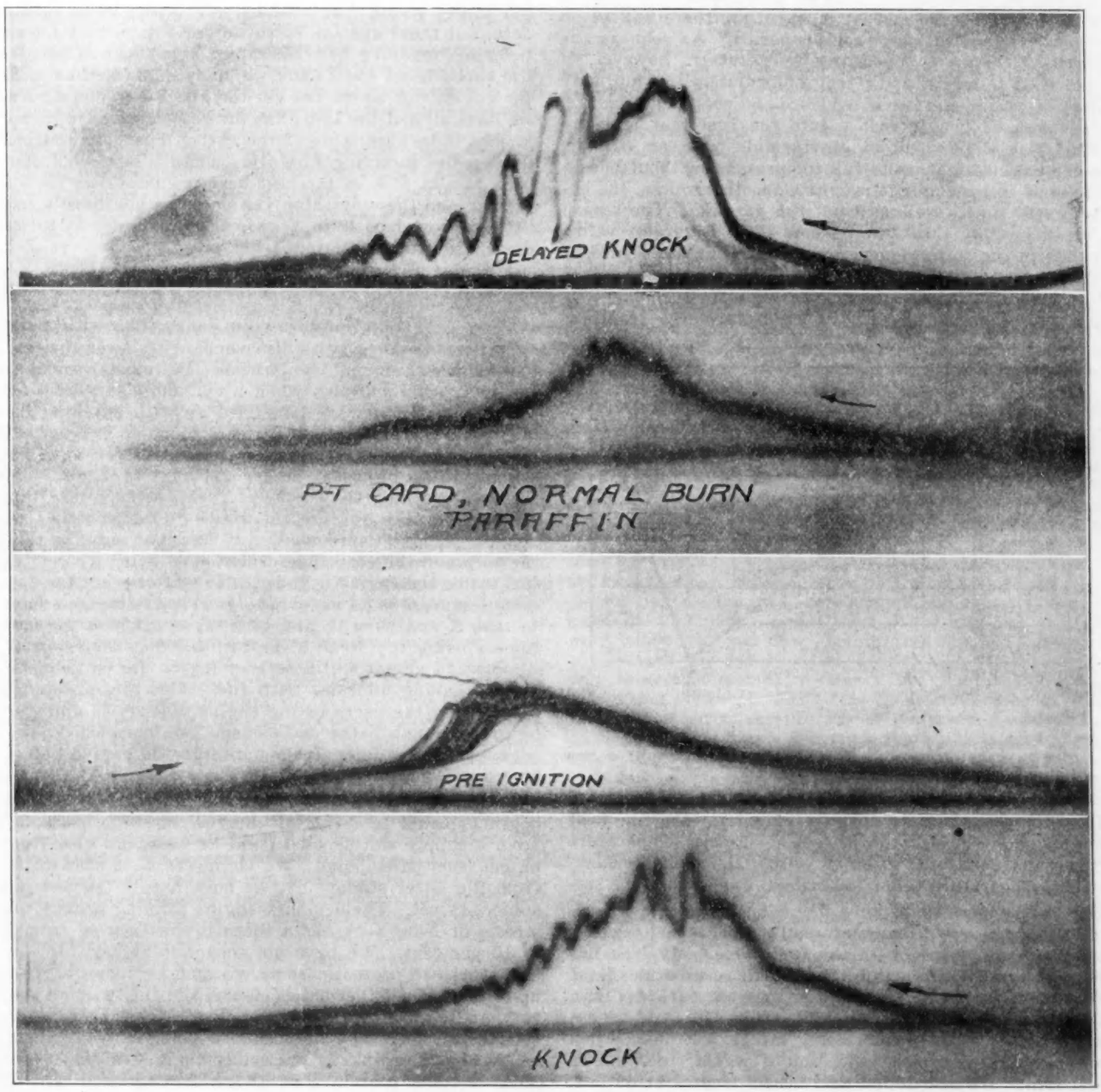
If our idea of the formation of secondary compounds is a true one, then if a fuel can be found which will burn by a single step from carbon to carbon dioxide and from hydrogen to water, it should be a fuel which does not give a knock. We started out by taking benzol. But we found that it was not a satisfactory fuel because of its free liberation of carbon upon burning. So we took this benzol and broke the double bonds between some of the carbon atoms and hitched on an extra hydrogen atom to each carbon atom, so that instead of being C_6H_6 it became C_6H_{12}. This, of course, made a material difference in the gravity of the fuel. And, incidentally, I might state that the gravity of benzol is only 28 deg., so that if

a man were buying it by gravity he would imagine himself to be getting a very poor fuel. The gravity of C_6H_{12}, the name of which is cyclohexane, is 48 deg.

Tests of Cyclohexane

Now here is the interesting thing about this cyclohexane. When we made it up and used it in an engine it acted differently from any fuel we had ever had. It took a long time for it to sink into our heads, but finally this fact came home to us: if a fuel burns by a single step from carbon to carbon dioxide and from hydrogen to water, the explosion will be absolutely independent of the compression, because the temperatures and pressures can only rise to such points in the cylinder as the products of combustion permit. That is, the temperatures of combustion cannot rise above the dissociation temperature of the products which result from such combustion. Consequently, when this fuel is used in an engine cylinder you get a pressure-volume card that looks like a steam-engine curve. And you can, without materially raising the explosion pressures, run this fuel on any compression up to the point of actual preignition, caused by the temperature rise due to compression reaching the ignition temperature of the fuel. This brief outline of our work with this fuel seems to indicate that the knock is certainly due to the formation of secondary or intermediate combustion compounds, detonatable compounds we call them, which let go unexpectedly and cause an abnormal rise of pressure.

Why then should lowering of compression prevent the

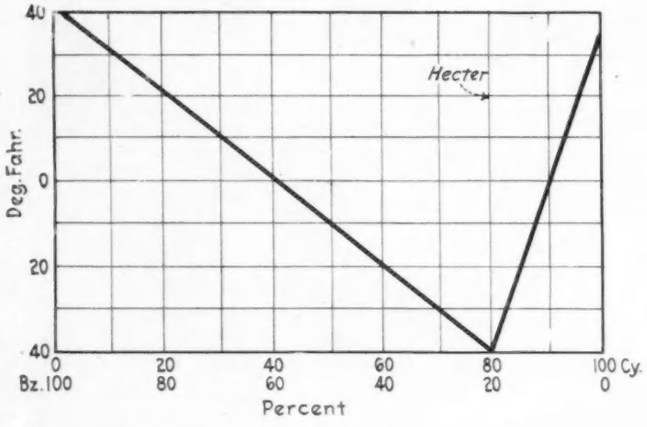


Pressure-Time Indicator Cards Secured by a Special Internal-Combustion Engine Indicator Which Show Typical Operating Conditions

development of the knock? Simply because lowering the compression results in a substantial lowering of the maximum combustion temperature within the engine cylinder.

For testing cyclohexane we built a Liberty engine having 200-lb. compression, and this fuel burned at such high compressions without any knock whatever. With the best grades of gasoline that we could secure we could not use compressions in excess of 125 lb.; in fact, without very careful selection of gasoline the compression could not be run up to more than 100 lb.

There is another interesting thing leading us to believe that there is a critical temperature beyond which you may not go without causing an entirely different type of combustion to take place in the engine. If you take an engine operating at 75 to 80 lb. compression, start to run it on kerosene and let it warm up, there will be no knock during this warming-up period. As soon as the engine gets up to operating temperature, however, it will start to knock, and it will immediately heat up, with loss of power and other evidences of poor performance. However, if you introduce into the fuel that is being used 3 or 4 per cent of ethyl iodide, you can run the same engine right up to full compression without knocking and accompanying troubles. In other words, the engine will run as well as it does on gasoline. The reason for this is, we think, that below 1200 deg. fahr. iodine exists in the form of molecular vapor, but when you get up between 1200 and 2000 deg. fahr. the iodine vapor breaks apart into an atomic vapor and in so doing uses up a considerable quantity of the heat energy resulting



MIXING BENZOL AND CYCLOHEXANE REDUCES THE FREEZING POINT OF THE MIXTURE MATERIALLY AS COMPARED WITH THOSE OF THE CONSTITUENTS

from the combustion within the cylinder. And the heat energy so used up will just ease off the temperature curve, flatten it out, in other words, and hold the maximum temperature below the critical line so that the secondary explosive compounds will not be formed.

There are a great many interesting phases and peculiar things in connection with the fuel game. My idea has been to present this subject to you more as a means of stirring up your interest and exciting your curiosity than supplying any fundamental engineering data. As an example of one of these interesting things, we found, when we investigated cyclohexane, that it would freeze at 42 deg. fahr. We also found that benzol freezes at 43 deg. fahr. Consequently, neither of these compounds of itself would make a satisfactory fuel, especially for airplane work where temperatures considerably below the freezing point of each fuel are prevalent. We found out this very interesting thing, however. If you take some cyclohexane and some benzol and mix them, the freezing point of the mixture is considerably below that of either constituent. By mixing them in the proportion of substantially 20 per cent benzol and 80 per cent cyclohexane, you get a freezing point for the mixture of substantially 40 deg. below zero, fahr. If we had not the facts in connection with this statement I know you would not believe that if you take two fuel compounds each one of which freezes at a comparatively high temperature and mix them together in certain proportions, the freezing point of the mixture can be reduced 80 deg. It is simply another case of molecular energy making such a thing possible.

I might go on into various interesting experimental data, but there are one or two other things that I want to bring out. We have all talked about carbon causing the knock in an engine and we know that when we clean the engine out we do not get the knock any more. And we have all had the idea that the reason we have carbon knocks is because some of the carbon heats up and preignites the incoming mixture. That is not what happens at all. One of the best heat insulators we have is carbon, and the only thing you do when you have a nice little carbon deposit in a gas-engine cylinder is to cut down the rate of thermal transfer.

SECURING BETTER ENGINE EFFICIENCY

One of our big problems in connection with fuels, therefore, seems to be to discover how to lower the temperature peak during combustion. We must remember, however, what happens when a cylinder is cooled too much. Your crankcase gets filled up with anything but oil. The big problem then seems to be to get a more efficient regulation of temperatures. And you have got to make this a problem whether you want to or not. The factors governing the supply of fuels are such now that we have to take our present grade of fuel whether we want to or not. Consequently, we have to study the relationship and the conditions which exist after we get the fuel inside the engine cylinder. No matter what the fuel manufacturers hand us, or where it comes from, we have to take it and burn it, and give satisfaction to the customers using it. None of us believes that the internal-combustion engine business is going to die out because we are having difficulty with fuel. But the amount of satisfaction the users of the engine will get is going to be proportional to the enthusiasm, pep, chemical knowledge, etc., that the engineer puts into the engine before he turns it out.

So I think it is only well at this time that we should begin to think in terms of the fuel question, not only from a supply and demand point of view, but also from an efficiency standpoint. We engineers have a lot to do from the latter standpoint; we have hardly touched the subject as yet. The ordinary engine running around the streets of New York has a thermal efficiency of from 5 to 10 per cent. We have got to get it higher. In our own work we have run some common ordinary engines up to 29 per cent thermal efficiency, and this without any very great amount of work on them. This leads us to believe that there is a possibility of going far beyond the range of our ordinarily prescribed limit of 25 to 30 per cent. I think that in 5 or 10 yr. from now it will be common practice to secure in the neighborhood of 35 or 40 per cent thermal efficiency.

Remember that a problem is what you think it is. If you think an engine can run only 10 hr. without repair it will run just that length of time. If you think it can run 100 hr., the chances are it will. If there is any one thing the war has demonstrated to us, it is that we have not exhausted anything like the mechanical possibilities of any device. Anything that man creates is only a physical representation of his mental conception of it. If some one should come here from some other world he would get a very bad idea of the mental conception of our automotive engineers, if they do not get busy on the little simple problems of settling this fuel question. In this talk I have shown where I think the problem lies. No matter what kind of injection devices or other instruments you may have, there is the problem of finding out how the fuel acts after it is inside the cylinder, and we have got to work out that problem. And this problem can never be solved by any one individual. It is going to be solved by the oil and the engine people and every one else working together.

A BATTLE VIVIDLY DESCRIBED

A LETTER that is characterized by an Army officer who sends a copy of it as "the most vivid description of a battle I have read," was received recently by a mother in this country from her son who was recovering from a wound at a central hospital in France.

"I am not allowed to tell you from where we went over the top, but I can say that we were in the hottest and bloodiest fighting of the drive that smashed the Hindenburg line. We hiked with light packs 20 miles to the trenches and then fought all night, driving the Germans out of their front line outposts. The next day we spent in the trenches under heavy gas and high explosive shell fire. Luckily we had only two killed and two wounded at that time. We got very little rest as we had to wear our masks almost all day. 'Jerry' evidently knew we were coming over and so tried to shake us up as much as possible. That day I saw many ghastly sights of men dying and wounded, but nothing in comparison with the following day.

"We started for the front line the next morning, an hour before daylight, and there formed in No Man's Land, to go over. 'Jerry' had his wind up and must have seen us. His artillery and machine guns opened up on us, and as we had no cover but the shell holes we suffered heavily. My nerves were on edge and I was in a cold sweat until their first high explosive came over. It was a 5.9-in. and landed right in our group, wounding or killing all of the twenty men. The shrieks and moans of the wounded men chilled my nerves to a standstill; it was odd to me to feel a less degree of apprehension coming over me. All I wanted was to get going where I could kill something.

"At the zero hour, just as the sky began to get gray, our artillery started, and at the same time the machine-gun barrage opened up. The Australians, who backed us up, said that the barrage was the heaviest they had ever seen. After a few minutes of this, the first and second waves went over, and in the semi-darkness, with the German shells dropping all about us, we followed in the third wave. The noise was deafening—I cannot hear very well yet. All orders had to be given by signals. The ground was strewn with our dead, dying and wounded. The poor fellows who were down cheered us on as we slowly walked over them behind our barrage. The tanks, the first and second waves were supposed to mop up all the dugouts and machine-gun nests, but in the poor light, when the forward movement was carried on, they must have overlooked several nests which opened fire on us after they had passed over. The casualty list will tell the result. As we advanced the dirt and stones jumped up and flew about us, and under this hail of bullets the men were dropping very fast. The boys were certainly well disciplined and made of the right stuff. With many of our officers wounded and most of our 'non-coms.' out, they kept on steadily rushing the machine gun nests.

"One bullet smashed my rifle; another plugged my canteen and the water running down my leg made me think I was hit there. Two bullets bounced off my helmet and the same instant numbers one and four, gunners with my squad, went down with hits. Number two picked up the Lewis gun, but three bullets had put that out of business. We then had the good luck to spot the machine gunners who were firing at us. They were only 100 yd. away, but we couldn't see much more than the top of their helmets. With rifle fire we got every one of them. At this time I got the bullet through the left side of my neck. It went in just to the left of the jugular vein and came out to the left of the back bone. It dropped me; I thought that I had been hit with a club. One of the men in my squad gave me first aid. While I was able to get up again I was very dizzy. I could not go far, so I rolled into a nearby shell hole with a couple of dead boys. They were lying there close together both with their hands on the beads of a rosary which one of them had about his neck. I saw many American boys die that day. They all passed like heroes with a smile on their lips and a cheer for us to get 'Jerrys.' As far as I know our boys took no prisoners. The field was covered with their dead.

"While lying in that shell hole I heard and spotted another nest of machine guns. Crawling up on it I burned it out with the five Mills grenades I had. When the first grenade landed you should have heard them yell 'kamerad.' The second, third and fourth quieted them. The fifth grenade silenced them. Afterward I looked into that nest. It contained two machine guns, one anti-tank gun and fifteen dead 'Jerrys,' who were blown beyond recognition. There wasn't a steel hat worth the taking. Later the Germans sent over a smoke screen and under cover of it I went back to the first-aid station. On the way I saw many of my chums who were either dead or dying. I gave them all the help I could. One poor fellow who had been shot through the leg, both eyes put out and one arm smashed, I carried on my back. The only thing that seemed to concern him was his folks. He feared that his people would hear about him and be worried. I won't attempt to describe any of the scenes I saw on the way out, for the words fail me. There was a dead 'Yank' every 10 yd.

"After reaching the first-aid station I was classed, at my own request, as 'walking wounded.' From there I walked back with others to a point where a lorry picked us up, and after a long ride we finally landed in a casualty clearing station, where my wound was redressed and I received the first inoculation against blood poisoning. This was about 9 o'clock at night. The place was so crowded that I had to sleep on the floor rolled up in a couple of blankets, but after two whole days without sleep I rested very comfortably. The following day I was put on a train and shipped to this hospital. Conditions are ideal; if I could receive some of the mail that is on the way to me I would be almost happy. My wound is almost healed now, and I am beginning to dread the time when I must leave this comfortable place. I expect to be kept here a few weeks longer. From the way matters are progressing at the front, I think it is quite possible that peace will be concluded this winter. The Huns can't hold us. We are beating them at every turn."

—*Army and Navy Journal.*

Tractor Drawbar Implements and Their Hitches

By F. N. G. KRANICH[1] (*Member*)

MINNEAPOLIS SECTION PAPER *Illustrated with* DRAWING

THE implements that go with a tractor have apparently not as a class received the consideration due to them. We see advertisements of the tractor everywhere. Pictures of tractors are published with details underneath of an excellent job of plowing or perfect disking; pictures of them harvesting and a legend of the excellent job of harvesting being done.

All this seems to me a rather false pretense, if I may so state, because it is the implement that really does the work the farmer has to do, and although the tractor draws it or pushes it, whichever the case may be, the work that is being done by the implement makes for the success of the powerplant as a whole. At a demonstration the farmer will invariably look at the job of plowing. In fact, it is not uncommon to find that tractors are purchased because of a job of plowing that was done by the plow. That alone ought to bring us to a fuller realization of the fact that the implement which goes with the tractor is a big part of the program we have to work out.

I have heard tractor designers say that they had not thought of making certain parts to suit farm machines, because these were part of the implement and the implement men could readily adapt the implement to suit the tractors. I believe that the sooner we realize that the implement has a function to perform as important as that of the tractor which furnishes the power, the better it will be for the industry as a whole. We all know of a great many implements that cause loss and make trouble for the tractor. Much of this is due to the way in which the combination goes together; in other words, the way it is hitched. The whole program of feeding the world, which we have in agriculture, is largely dependent on the work of farm implements. They really do the farming.

IMPORTANCE OF MACHINERY IN FARMING

The history of the Nation as a whole is nothing more than the history of its agriculture and consequently of its farm machinery. Go back as far as we may, we find that civilization has grown only as fast as farm machinery has been developed. Farming machinery governs the growth of agriculture and is far more important in the program we are concerned with than the tractor.

The value of the implement as an accessory to the farmer's labor is seen in the fact that a bushel of wheat is now produced in 10 min., whereas with the old hand method this took 3 hr. and 3 min.; corn is now produced in 41 min. as compared with 4½ hr., and corn shelling has been reduced from 100 min. per bu. to 1 min. To cut an acre of hay once took 11 hr., whereas this is now done in 1½ hr. All this improvement is due entirely to the work of the implement as a part of farming.

The whole answer to the question of food production is *machinery*. It has become an invaluable part of the farm operator's equipment, and the tractor comes in as an accessory. We find some automotive apparatus that has really become a part of the farm machinery. This is particularly true of the motor cultivator. About 83 per cent of farm work is machine work; that is about the percentage of the labor put on a growing crop. This makes me all the more sure that farm machinery will receive greater consideration from the builders of automotive apparatus. To the draft implements as well as the belt machines, there is a certain relation we cannot get away from. The tractor is, after all, just a means to an end. It enables the farmer to get more out of his implements and tools, to use larger units of these and to do more work than he could otherwise in the same time.

With the aid of all this machinery that we have, automotive apparatus being, if you will, combined with it, we produce about two-fifths of the world's wheat, more than half of the cotton and over three-fourths of the corn. We are only one-sixteenth of the human race and only about a third of our people live on farms. What we accomplish is due to the development of machinery. Today one man can do the work that it took thirty men to do in 1880.

EVOLUTION OF AGRICULTURAL MACHINERY

I have read somewhere that the evolution of machinery in connection with agriculture can be divided into (1) the period of hand methods, when everything was done by man power, and crudely; (2) the period of transition, when some general machinery came into use for the heavier work; and (3) the period of fully adopted farm machinery. We are ready now to add another, (4) the period of automotive farm power. Farm power has become a part of agricultural progress.

Plowing, it has been said, is "the peak load in agriculture." We learn that it takes more power to plow the fields each year than is used in the combined industrial plants of the country during the same time. To plow even an acre of ground with the common 14-in. walking plow requires walking 8½ miles, and to cover 1 sq. mile we have to walk over 5000 miles. The tractor is doing away with that hard, slow work. It is a part of the modern development, a means to an end.

The types of plow in use are various, but not so numerous as formerly. One plow manufacturer told me recently that formerly he had over thirty different types of bottoms in his different branch houses to suit the requirements of the territories in which his product was sold, whereas now, since the tractor has become a big part of his business, he has but six. Special bottoms have now become really a whim of either the branch manager or the farmer. There are two main types of plows, the flexible-beam, each beam fastened to the bottom independently, and the rigid-beam, all beams on one frame and traveling together. It has been found that where the land is very irregular and yet a constant depth of plowing is to be maintained, the flexible-beam plow gives better satisfaction, particularly if large units can be

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used, say four, six or eight plows. These, however, are very difficult to adjust, and since they come knocked-down, a pretty good plowman is required to set one up and get it properly adjusted to the work. The ordinary rigid-beam plow, used commonly with the small tractor, is comparatively simple. There is but one way to set it up and the directions are explicit.

Bottoms vary, of course, with the work the farmer has to do. To plow well, it is necessary that the action of the soil on the plow bottom be such that the soil will loosen up and disintegrate. In other words, the particles of soil should separate and tend to pulverize. This is essential and brings us to a fuller realization of the important function a plow has to perform. It has certain work to do. Perhaps this can best be likened to bending of the sliding leaves of a book one on the other. It is a big part of the plow manufacturer's problem to make a mold board of such shape that it will turn the furrow slice, one particle on the other, and mellow it.

Hitching

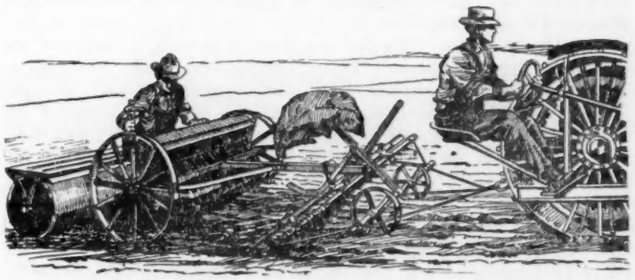
The hitching of a plow to any sort of tractor frequently defeats all the work that the plowman has put in on the bottom. Perhaps most of us who go to demonstrations have noticed this every year. We find plows of the same make, in practically the same soil and at same speed, doing work of very different quality. To any one watching the demonstration last season at Salina, this was apparent. The variation was caused by the fact that the plows were hitched differently. To know just how plows should be hitched to get the best results is difficult to determine.

The tractor man, of course, wants a hitch in the center. That is ideal. His purpose is to make the best showing for the tractor. The plowman wants to hitch in what he calls the "center line of draft." The plow that has been designed for that runs best and does its best work when hitched that way. Professor Sanbourn, in some tests in Missouri, found that 55 per cent of the total draft of the plows was used to cut the furrow, 35 per cent in friction of the sole and heel on the soil and 10 per cent in lifting load. At the Winnipeg tests made several years ago two gangs of men plowed in adjacent fields, cutting the same depth with the same number of bottoms, being checked by the same observer, yet the final result showed the draft of one gang to be about 50 per cent more than that of the other. It was found to be a question of proper hitching and sharp plows. The load on all three wheels of the plows should be equal. Any operator can check this readily by taking hold of the wheels and slipping them on the ground, determining whether a plow is set right. The rear wheel bothers most of us. The draft of the plow can ordinarily be increased as much as 20 per cent by having the rear wheel set wrongly, the plow riding on the sole or the heel. Most plows have a loose piece on the rear end of the land side that can be removed and changed as it wears. This piece frequently rubs on the bottom of the furrow. The tractor operator can easily adjust the rear wheel on nearly all modern plows; provision is made for just that thing. We can make the best showing by getting a proper hitch and properly adjusting the plow.

Draft of Implements and Tractors

The draft varies all the way from 3 to in excess of 20 lb. per sq. in. of furrow section. In sandy soils, like those in Michigan and around the lakes, the draft will run 3 lb.; in some soils in Illinois and Texas 20 lb.; and in the West much more. It is, therefore, well worth while to train operators to understand thoroughly the hitching of the plows. It is important that the plow be so set that the tractor can do its best work. We find tractors advertised as two-plow, three-plow and four-plow, but in practice in some conditions "two-plow" tractors will hardly pull one bottom. In other cases they can pull three.

The center line of draft on plows is often talked of mysteriously. It is assumed by most plowmen that this center line of draft is about 2 in. inside the land side of a bottom, and in the same proportion in two, three and four-bottom units. Some tests were made this summer by Professor White to find the center line of draft on a plow; in other words, to determine definitely the point of least resistance, rather than assume it to be "2-in." position. I had the privilege of working with him. The test disclosed some curious things. We had a tractor with a drawbar the total width of the machine, with holes punched in it every 2 in. all the way across; in other words, a drawbar that gave us an opportunity to hitch from the outside of one wheel on the right to the outside of the other wheel on the left. The purpose was to take two, three and four bottom gangs, move the hitch and make dynamometer tests to find the point where the plow pulled "lightest," the assumption being that this would naturally indicate the line of least resistance—in other words, the center line of draft. We found, however, that the hitch by which the plow could be pulled most easily did not necessarily determine the center line of



Typical Example of Implement Hitches

draft. The plow ran lightest when it was hitched on one side, but the quality of the plowing was very bad. We found that this was due to the fact that the plow was hitched badly. This was evident even in a photograph. It was such a poor job of plowing that I believe the farmer would have ordered us off the field if we had not contracted to do the work to his satisfaction.

This revealed to us the importance of getting the two units coupled in harmony. We found that one hitch gave a draft of 1800 lb. on a four-bottom plow. That same plow hitched on the other side had a draft of 2395 lb., an increase of 44 per cent. We measured the depth every 40 rods across the field. In another case the decrease in the draft due to a good hitch was a trifle over 30 per cent. We found that on one three-bottom plow the draft was decreased 22.1 per cent by a good hitch; on a two-bottom, 17.4 per cent. These figures emphasize the importance of this matter. A tractor can be made to show good or bad performance simply by hitching correctly or incorrectly. A statement of test results that does not include mention of the conditions under which the tests were made is of little value. It is not convincing to state that one tractor used less fuel than another in plowing; that in one case (not explained)

it cost 7 cents an acre and in another 12 cents. Very seldom, in any plowing tests or demonstrations, going back even as far as the Winnipeg contest, has the relation of hitch and draft been recorded or considered. I know it was not at Salina or at Fremont. Even in the work that was done at Fremont two years ago, no record of the draft was kept so far as the hitch was concerned. We should all realize that the point is important. If manufacturers propose to publish figures of results of tests of this sort, the item of hitch, since the draft can be so affected by it, should be included.

Not much work has been done, at least for publication, to get the draft of other implements that go with the tractor. Plowing is, of course, the big work the farmer has to do, the work with which he is most concerned; yet he is using the tractor for other things; he must do so to make it of real economic value to him. Tractors are made to use with the present line of implements, but I think that not many farmers have found it profitable to use a tractor and two or three mowers, with a man on the tractor and one on each mower. The solution of this part of the problem is larger units for the men to handle. A 10-ft. mower instead of two 5-ft. ones does much better work, and better hitches can be made to reduce the side-draft on the tractor. A 10-ft. disk harrow, just as sharp as practicable, required a 790-lb. pull to disk-plow ground. A 10-ft. pulverizer took 700 lb. The binders, mowers and drags run very light in draft as compared with plows.

If plows are properly hitched, nine-tenths of the complaint of high cost of plowing will, I think, be eliminated, because we can then plow more cheaply, needing less drawbar horsepower and, of course, less fuel. The thing that appeals to me most in the whole situation is the question of tractor hitch to suit the implement. As I have said, if the men who sell tractors would give more attention to the implement the industry as a whole would gain.

ROLLS-ROYCE AERONAUTIC ENGINE

THERE is no doubt that the conception of the Rolls-Royce aeronautic engine is extremely good, but no one will gainsay the fact that the care exercised in manufacture and the elaborate operations through which the various parts have to pass are in part the reason for its success. This refinement necessitates the passing of certain parts through fifty or sixty operations that might be easily carried out in a comparatively small number if superfine finish were not desired or required.

The Rolls-Royce "Eagle" engine, originally designed as a 200-hp. unit, developed 255 hp. on the first brake test. Diligent research and experiment were pursued with extraordinary results, as will be seen in the following record of official brake tests, all made without any enlargement of the dimensions or radical alteration in design. A twelve-cylinder engine, 4½-in. bore by 6½-in. stroke, developed in March, 1916, 266 hp. at 1800 r.p.m. By July the power was increased to 284 hp.; nine months from this date, in September, 1917, it had risen to 350 hp., and in February, 1918, 10 more horsepower was added, making the total 360 hp. In addition to the "Eagle," a smaller engine giving 105 hp. at 1500 r.p.m. was turned out under the name of the "Hawk."

The "Eagle" engine was used in the large Handley-Page machine and in the successful long-distance bombing raids into Germany. In 1916 another engine for fighting planes was added to the list, under the name of "Falcon," and was almost exclusively used in the Bristol fighting plane. The increase in the power developed by the "Falcon" engine, which has a 4-in. bore, was as follows: April, 1916, 206 hp. at 1800 r.p.m.; July, 1918, 285 hp. at 2000 r.p.m.

From the stamping plant through the machine, gear-cutting and grinding shops and welding department, the care with which each engine is turned out is apparent. Take apart a cylinder which has a stamped sheet-metal water-jacket welded externally, and the original billet is found out of which the cylinder was made, but reduced almost by half when it is ready to receive the valve cages, and during the process of removal of the metal and forming into proper shape the piece is subjected to several heat treatments so as to bring the metal to that stage of perfection needed for the work it has to perform. The elbow cages that are fitted to the cylinders might be cast and cored, but the valve cage is an actual solid stamping, and the right-angle bend through the elbow has to be bored out by special machines.

One point illustrates the care in the choice of metal and the multifarious operations through which each part has to pass. A crankshaft stamping with extension piece on the rear and about 1 ft. long is cut off, and test pieces of this metal, properly numbered with each crankshaft, are passed through the same treatment as the crankshaft itself, and then subjected to minute examination by highly skilled engineers. The actual manufacturing side of the work would naturally be very similar to the manufacture of a car engine, but one obtains a better perspective of what an engine is subjected to by passing from the erecting and manufacturing shops to the engine testing shop, where the ear-splitting reports from the open exhausts of a number of engines being tested at the same time are heard. Here one sees how dissimilar the aviation engine is from the car engine. It is almost impossible, without having actually witnessed it, to picture to oneself, a twelve-cylinder engine running at 2200 r.p.m. against a brake test. As the exhaust ports are on either side of the engine, the cylinders being placed in the form of a V, it is possible, by passing on either side, to look into the combustion chamber and see the valves rising and the spit of the exhaust, and, what is almost incredible, that the exhaust valves are actually red-hot and run in this condition for hours. Little wonder is it that the valves have to be made of superfine material and of particular form.

The variation in the color of the flame of the exhaust, due to strong and weak mixtures, makes it quite possible to test the good running of an engine by the color of its exhaust. The strength of the mixture has necessarily to be altered according to atmospheric conditions and the altitude to which the pilot desires to climb.

No doubt airplane engine practice of the last four years and the advance that it has made will be reflected in a very marked degree in the automobile, not necessarily by fitting large airplane engines in cars, but by applying to car practice the knowledge that has been gained in manufacture.

The Rolls-Royce works had in 1907 an area of 5312 sq. yd., and during the war this was increased to 67,935 sq. yd. At the present time the payroll is somewhere in the neighborhood of 8650. —*Motor* (London).

Airplane and Seaplane Engineering

By COMMANDER H. C. RICHARDSON,[1] U. S. N. (*Non-Member*)

ANNUAL MEETING PAPER *Illustrated With* PHOTOGRAPHS AND CURVES

THE problem confronting the Navy was largely determined at the time the United States entered the war by the fact that the operations of the German and Austrian fleets had been reduced principally to minor raids from the fleet bases at Kiel and Pola, and the only real seagoing operations comprised the activity of submarines.

The work of the seaplanes, therefore, was primarily reduced to that of cooperation with the fleet in reducing the submarine menace. This naturally led to the establishment of coastal stations in France, Italy, England, Scotland and Ireland. In these operations it was possible to operate seaplanes from shore bases in practically every case, and the development of work with the fleet became a minor consideration.

Some of the seaplane bases, however, were sufficiently close to enemy territory to be within raiding distance of enemy planes of both land and water types, and it became necessary for the Navy to extend its activities to the use of land planes for the protection of seaplane bases, while naval aviators also participated in big bombing raids on German and Austrian territory.

I refer to these matters in this general way, not to describe the activities, but to show that in naval work both land and water planes were used, and why the Navy problem was in general restricted to operation from shore bases rather than operation from ships. Activities, however, were not confined to shore bases in Europe. Stations were established on the Atlantic coast, principally for the purpose of submarine patrol and for convoy work from the principal ports from which our troops and supplies were sent abroad.

TYPES OF PLANES DEVELOPED

The work of seaplanes abroad was that of submarine patrol and convoy work, and this having been determined on, all efforts were made to obtain the most suitable seaplanes for the service. The principal work was done with two types of seaplanes, namely, the HS-2—the single-motored plane developed from the HS-1—and the H-16, a copy of the English seaplane of the same type developed as a result of Commander Porte's experience with the original America and subsequent types developed therefrom. Finally, the F-5-L type was developed from English designs for manufacture in this country by the Naval Aircraft Factory at Philadelphia. The HS-2 and the H-16 have proved well suited to the work required, but the F-5-L did not enter production early enough to get into active service before the armistice was declared.

The Navy did not attempt to develop land plane types, but accepted and used those which had been developed and produced for the Army, adopting for this purpose the English Handley-Page, the Italian Caproni, and the Army DH-4 and DH-9.

In order that pilots should be trained for this service, it was necessary to adopt training planes, and for this purpose the Navy developed and used the Curtiss N-9,

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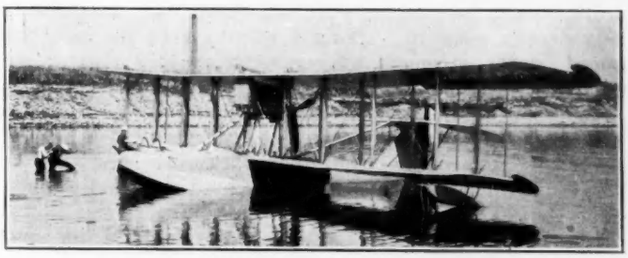
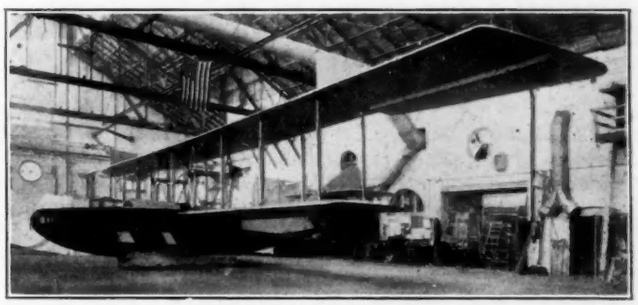
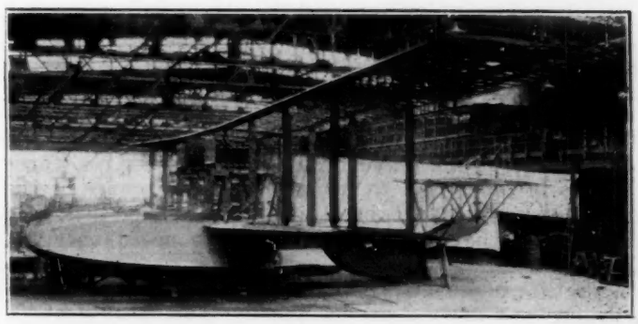
THE HS-2 NAVY SERVICE PLANE WHICH WAS DEVELOPED FROM A TWIN-ENGINED SEAPLANE ORIGINALLY DESIGNED FOR THE ARMY



THE HS-2-L SEAPLANE USED BY THE NAVY



A THREE-QUARTER FRONT VIEW OF THE H-16 SEAPLANE



THE F-5 SEAPLANE USED BY THE NAVY

the R-6 and the R-9, the Aeromarine and Boeing seaplanes, and the F-boat, and also experimented with a number of miscellaneous types, such as the Gnome scouts —both biplane and triplane of Curtiss and Thomas manufacture—and the Gallaudet D-5. The most successful of these training planes was the N-9, particularly after the original float had been modified and later on after the substitution of the Hispano 130-hp. engine for the OXX 100-hp. engine. This plane was a biplane tractor with a single center float, having wing tip balancing floats. It was remarkably strong and could perform practically all sorts of maneuvers. Although in training work it was frequently wrecked, there were remarkably few deaths resulting. This I attribute to its moderate speed, great strength of construction and tractor arrangement, which made it suitable for training purposes.

As soon as it was determined that seaplanes of the flying-boat type were to be used in service it became necessary to provide preliminary training in a type of seaplane which more nearly represented the conditions of operation of the big boats. For this purpose the F-boat originally developed by Curtiss for sporting and for naval use was modified and adapted to instruction purposes.

I shall later on describe and illustrate the principal types referred to.

So far as the aerodynamical and mechanical features of construction are concerned, seaplanes differ very little from airplanes, the principal difference being the use of the landing gear suited to operation from the surface of the water instead of from the land. The proportions are, naturally, somewhat different, and the performance is different, primarily, because of the greater inertia due to the increased weight involved in the seaplane construction. But bearing this in mind, the details of construction of seaplanes are substantially the same as those used in airplanes.

Factors Affecting Performance

It will now be of interest to consider the principal factors which affect performance, as it is necessary to understand these completely to develop a design which shall perform according to the requirements of the service intended. For the purpose of illustrating the factors involved I have prepared a set of performance curves, which I believe will give a clear insight into this phase of the problem. The complete calculation of the curves shown is given in the Appendix, together with the formulas involved in the computations.

The performance in power flight is determined by the horsepower required and the horsepower available, and, of course, the latter must always exceed the former or power flight is not attainable.

In determining the power required there are two principal factors involved. The first factor is that of the horsepower required to propel the planes with their load in flight. This horsepower I term the plane's e.hp. To determine it, it is necessary to know the form and disposition of the wing surfaces used, as well as the aerodynamic characteristics of the wing section employed. The lifting power of the wing depends on the area and the square of the speed of advance, and its resistance is also in proportion to the area and the square of the speed of advance, the speed of advance being the speed relative to the air itself and not the speed over the ground.

The lift of an airplane surface and its resistance to advance are determined by the lift and drift factors, which vary with the type of section used and also with the angle of attack at which the surface is presented to the relative stream of air. It has been found by experiment that these factors are influenced by the proportion and arrangement of the surfaces, the best results being attained with what is known as the monoplane surface.

Performance is improved by increasing the dimension of the wings in the lateral sense, over that of the fore-and-aft dimension. The ratio of these two dimensions is called the aspect ratio. As the aspect ratio is increased, it is found that the efficiency is improved indefinitely. But after an aspect ratio of 8 or 10 is attained the improvement in efficiency becomes less and less, and, practically, is not worth going after, because the dimensions become unwieldy and the gain in lifting power and efficiency may be more than wiped out, due to the increased weight and resistance of the structure required in employing it. It is largely on account of this difficulty that the biplane and the triplane have been used where large lifting power is required, even though in the latter cases the efficiency of the surfaces is reduced because of interference of the air flow, which is found to depend upon the gap ratio. By this is meant the ratio of the distance between superposed planes to the chord length, or fore-and-aft dimension of the wings.

Where the leading edge of the upper plane is forward of the leading edge of the lower plane the efficiency is improved over that where one plane is immediately above the other, and conversely. This arrangement is referred to as stagger and the condition of positive stagger, that is, with the upper wing forward of the lower wing, is generally adopted with the view of improving efficiency. There are limits to its usefulness because of the obliquity of the trussing involved.

Stagger may be adopted for various reasons, such as correcting the balance of an airplane in which the actual location of the center of gravity does not conform to that originally contemplated, or in order to improve the view of the pilot or observer, particularly if the latter is also a gunner.

The efficiency is improved if the upper plane has a greater lateral dimension than the lower plane. This disposition is known as overhang. There are limits to the extent to which this can be employed, on account of the structural difficulties involved.

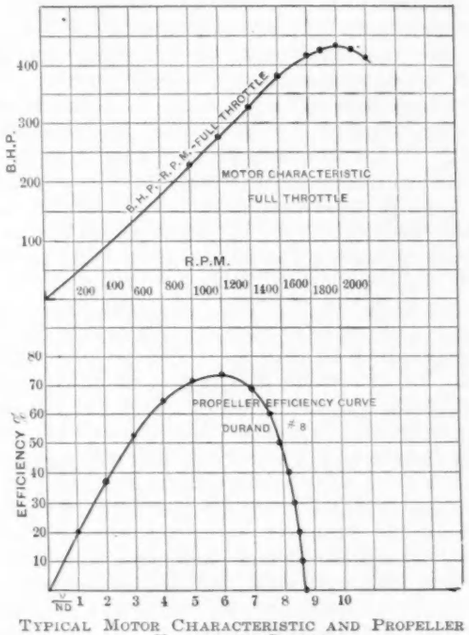
In the normal type of construction, the front and rear edges of the wings are parallel, although it is found that tapering the wings to a smaller fore-and-aft dimension at the wing tip improves efficiency. This arrangement is not satisfactory from a manufacturing point of view, as it involves different sized ribs at every station in the wings. All the above considerations have to be taken into account in determining the form and proportion of the wing surfaces.

Another factor is very important, that is the travel of the center of pressure on the wing surfaces. It is found that where wings have a cambered surface—which is usual in airplane construction because of the superior lifting power—the movement of the center of pressure is such as to cause longitudinal instability. Various devices have to be employed to overcome this. The most satisfactory and usual method is to employ an auxilliary surface at the tail of the airplane called the horizontal stabilizer, and the best conditions for stability are found when this rear surface has a smaller angle of attack than the wing surfaces themselves.

This difference of angle between the wings and the horizontal stabilizer is termed "longitudinal dihedral." The stiffness or steadiness of an airplane in flight depends on the area, proportion, section and angle of the

rear surface. Where great stiffness is desired, this rear surface may even assume the proportions of a second set of lifting surfaces which may be of monoplane or biplane arrangement, usually of smaller dimensions than the main planes. Where the rear surfaces are increased to nearly the proportions of the forward surfaces, the tandem biplane arrangement is approached.

For military purposes and for combating rough air conditions it is found desirable to have initial longitudinal stability, but it is undesirable to have this in a high degree on a military plane in which steadiness may be



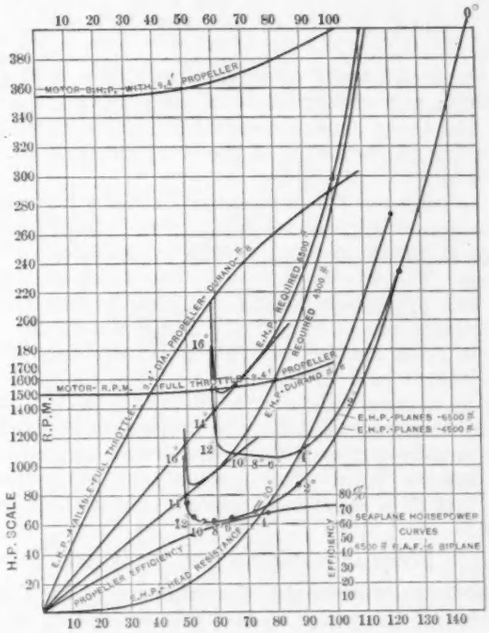
TYPICAL MOTOR CHARACTERISTIC AND PROPELLER EFFICIENCY CURVES

essential to the proper operation of a gun or of a bomb-dropping device. If the rear surface were completely fixed in relation to the forward surface it would be possible to proceed in horizontal flight at one definite speed only for the load carried, and ascending or descending could be accomplished only by increasing or decreasing the power, or by decreasing or increasing the load. These methods of control are not sufficiently accurate or active, and it is much more satisfactory to use additional surfaces, known as elevators, appended to the rear margin of the horizontal stabilizer, which by modifying the action of the stabilizer make it possible to proceed in horizontal flight at any speed from the minimum to the maximum flying speed, or to cause the plane to rise or descend. In some airplanes, in order to get the maximum of maneuvering ability, the horizontal stabilizer is reduced to a very small area; or, even, in some cases, is completely dispensed with, all being merged in the elevator.

In the original Wright machine lateral balance was maintained by warping the wings, but this method is unfavorable to strength in large structures, and the use of ailerons for this purpose has now become general.

In flight, airplanes are not always operated so that the trajectory conforms to the axis of the airplane, particularly when turning or when encountering side gusts, etc. As a consequence, unless what is known as the keel surface of the airplane is distributed equally above and below the center of gravity, there is a tendency for the airplane to roll one way or the other, depending upon the location of the center of gravity relative to the center of lateral pressure. To compensate for this effect, or to provide lateral stiffness under such conditions, it is usual to provide a moderate amount of what is known as lateral dihedral; that is, the wing tips are higher than the center portion of the wings; or else skid fins are placed immediately under or above the upper wings. These in general have the same effect as lateral dihedral. By modifying this arrangement the amount of lateral stability can be controlled to any desired degree. Again for military purposes it is desirable to have initial lateral stability, but not to such a degree as to interfere with controllability of lateral balance.

Directional stability is also affected by the location of the center of side pressure, depending upon its location fore-and-aft of the center of gravity. It is essential for steady flight that the center of lateral pressure at small angles of skew should not pass forward of the center of gravity. To accomplish this it is usually necessary to install a vertical stabilizer at the tail of the airplane. It is again desirable to have initial directional stability. And again, in a military plane, it is undesirable to have this to such a degree as to interfere with control of direction. As the airplane is symmetrical relative to the vertical fore-and-aft plane, it is unnecessary to provide any equivalent of the dihedral effect, and it is only necessary to append a rudder to the vertical stabilizer in order



HORSEPOWER CURVES OF THE RAF6 BIPLANE

to control direction. In some planes, where extreme maneuverability is desired, the rudder itself, in its neutral position, performs the functions of a vertical stabilizer as well as that of a rudder, and no vertical fixed surface is used.

LOCATION OF POWERPLANT AND CREW

Having given due consideration to the influence of the proportion, arrangement and disposition of the main supporting and control surfaces, it is next necessary to consider the service intended and the location of the powerplant and the crew. The possible arrangements are almost infinite, but in general it is desirable to locate the pilot centrally where he will have a proper view to enable

him to handle the airplane to the greatest advantage and this is particularly necessary in the combat plane. It is also essential that the gunner shall have as large and unobstructed a view as practicable, and that with the gun positions selected he shall be able to cover his arc of fire and as much of the surrounding sphere as is practicable, in order that there shall be no dead spots from which the enemy may approach without his being able to return the fire. This sometimes requires that the pilot himself shall be able to operate guns firing dead-ahead, or that additional gunners shall be placed so that they can cover arcs of fire not possible for the others to cover.

In bombing planes and, in particular, in night bombing ones, this requirement is of less importance, and the requirement that the bomb dropper shall have a proper view for the operation of the bomb sights becomes of prime importance.

In airplanes designed for long-distance flights or for bombing, it becomes necessary to have great power available and this requirement has lead to the adoption of multiple unit powerplants. Two, three, and as many as five powerplants have been successfully used for this purpose. The multiple-engine plane has the advantage that in case of damage to one powerplant it is usually possible to continue flight with those remaining; or, if still too heavily loaded to accomplish this, it is possible to glide for a long distance and thereby select a more favorable landing place, and often to avoid landing on enemy territory.

All these and many other considerations enter into the disposition and arrangement of the powerplant and fuselages, and these arrangements themselves have an influence on the performance of the wing surfaces because of interferences involved.

By winging out the powerplants a more favorable load distribution is imposed on the airplane structure and advantage is taken of this feature in designing the wing trussing. The effects of interferences and of the disposition and proportion of the wings or bodies and auxiliary surfaces are so complex that unless data are already available from similar designs, it is very desirable that the resistance and lifting power of the complete design should be determined from wind-tunnel tests of a model carefully constructed to scale in every detail. Such model test is usually deferred until the design has approached some definite form after preliminary estimates have shown that it is capable of approaching the performance desired.

Form and Proportion of Wings

In preliminary estimates the influence of the form and proportion of the wings is carefully estimated, and from these estimates a fairly accurate approximation of the horsepower required for the planes is derived. To arrive at the total horsepower required, it is next necessary to consider the horsepower required to overcome the head resistance. In order to do so, it is necessary to have accurate knowledge of the resistance of all elements of the airplane structure exclusive of the wings, which are exposed to the action of the wind in flight.

To reduce the resistance of these elements to a minimum, streamline forms are adopted wherever practicable, and even the truss wiring is made up of streamline form; or, if this is not found practicable these wires are covered with false streamline covers of wood or metal. It is found that the reduction in resistance more than compensates for the additional weight involved in applying these false covers.

The resistance of the fuselages, radiators, engines, tail control surfaces, elevator rudder, aileron horns and all other elements is computed in detail, and account is also taken of the obliquity of these elements to the flow of the air. Such obliquity is found to exert an important influence on their action. For preliminary estimates, it is customary to determine the resistance of these elements for the position assumed by them at some speed intermediate to the low flying speed and to the high speed attainable with full power, and then to assume that the resistance of these elements is proportional to the square of the speed for speeds above and below the intermediate speeds selected. This is most handily done by assuming that the resistance of these elements is represented by a flat surface exposed normal to the wind, which would have the same resistance as the aggregate of these elements. This suppositious surface is what is referred to when we speak of the "surface of equivalent head resistance." In the example which I have chosen to illustrate, "the equivalent head resistance" is assumed to be 20 sq. ft., and the horsepower required to drive this head resistance through the air is indicated on the curve denoted head resistance horsepower. By compounding the ordinates of this curve with the ordinates of the plane's e.hp. curve we derive the total e.hp. required curve.

We have next to determine the total brake horsepower available in order to determine the performance of the airplane. To determine this curve, we must first know the full-throttle characteristic of the engines to be used. This characteristic is indicated in the example showing the brake horsepower available at different speeds.

The next thing to be determined, and the one having a most important influence on the performance of the airplane, is the propeller characteristic. To date the progress in propeller design has been far from satisfactory, and although good results have been obtained, the best results possible have seldom been approached. In the selection of the propeller, one of the first considerations is to determine what feature of performance is most important, for it is necessary to select the proper dimensions with a view to gaining the best results for the service intended. For instance, if high speed is of greatest importance, the propeller to be selected will differ materially from that which would be required if great climbing power is desired, because the greatest climbing power will be attained at a speed much lower than the maximum rate. Or, it may be a question of selecting a propeller which will give the greatest efficiency at cruising speed, and this propeller will usually differ from that selected in either of the preceding cases. In some cases it may be desirable to select a propeller which will give the best all-round performance rather than for a particular condition.

In seaplane work a problem arises which is not found in the land airplanes. This problem is that of obtaining the greatest reserve of power to overcome the resistance of the float system, because it is desirable to have the greatest possible reserve to accelerate rapidly on the water, so that the get away may be made in rough water with the greatest possible rapidity, thereby reducing the punishment which the seaplane suffers under such conditions. For a heavily loaded seaplane this consideration may be of vital importance.

Efficiency of the Propeller

It must be understood that the efficiency of an airplane propeller is absolutely dependent upon its speed of advance through the air, as is also the power which the propeller absorbs in flight, the result being that even though the

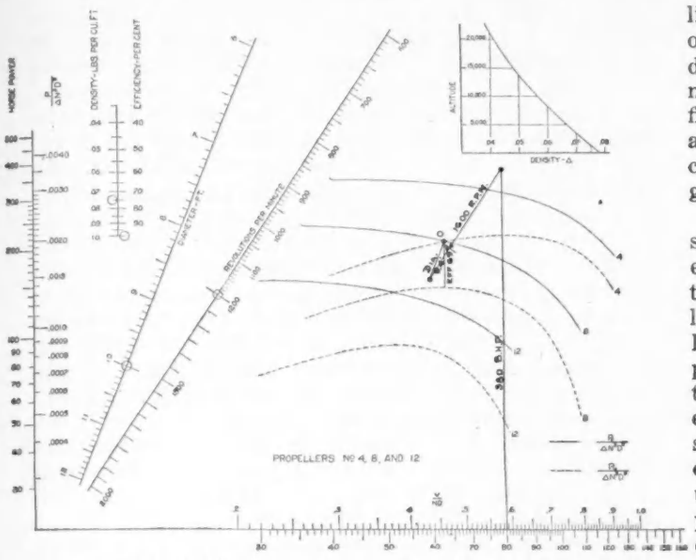


CHART FOR DETERMINING THE DIMENSIONS OF PROPELLERS

full throttle is used the engine cannot make its full revolutions until a good flying speed is attained, with the consequence that full power of the motor cannot be realized until flying speed is attained.

The efficiency of a propeller is dependent upon a function of the velocity and the number of revolutions and the diameter of the propeller represented by the fraction $\frac{V}{ND}$. The efficiency, the torque and the thrust, the horsepower absorbed and the horsepower delivered are functions of this quantity, in which velocity, the number of revolutions and the diameter must be expressed in the same units.

The influence of this factor is indicated on the propeller efficiency curve based on the values of the fraction $\frac{V}{ND}$. When this fraction equals 0.2 the efficiency of the propeller indicated in the example is only 37.5 per cent. The maximum efficiency is attained when the value of this fraction is 0.59, the maximum efficiency indicated in this case being 73.2 per cent.

In the example chosen I have used a Durand propeller No. 8, the characteristics of which have been determined by wind-tunnel tests, as reported in report No. 14 of the proceedings of the National Advisory Committee for Aeronautics—1914.

To derive the dimensions for this propeller I have assumed that it is desired to attain the best results at 80 miles per hr. with a Liberty engine operating at 1600 r.p.m. and developing 380 b.hp., as shown by the motor characteristic. In Professor Durand's report he has adopted Eiffle's logarithmatic chart, and I shall now indicate how the diameter of the propeller is determined.

On the chart at a speed of 80 miles per hr. erect an ordinate equal to 380 hp. taken from the scale on the left side of the chart. From the top of this ordinate next draw an oblique line parallel to the line indicating the speed, and draw this line of such a length and in such a direction as to represent 1600 r.p.m. on the scale starting with the origin at 1200 r.p.m. From the extremity of this line next draw a line parallel to the line giving the diameter scale, and taking the distance from this point to its intersection with the propeller characteristic for the propeller No. 8 we find that this line intersects at the point O. Transferring the length of this line to the diameter scale and measuring in the direction in which it is necessary to draw this line to make it intersect with the propeller's characteristic, we find that the proper diameter to use is 9.4 ft., indicating an efficiency of 69 per cent. By the use of this ingenious chart it is possible to select a proper diameter for a given set of conditions by a simple graphical solution.

The diameter now being determined, it is next necessary to determine the performance of the combined engine and propeller, and this is done as follows: On a transparent sheet of paper or tracing cloth a base line is drawn and, from any convenient point on this line, another is now drawn parallel to the scale of propeller diameters and a distance is laid off representing the diameter of the propeller on that scale. From the extremity of this line a new line is drawn parallel to the scale of revolutions per minute, and on this line is indicated the revolutions per minute of the powerplant, using the scale of r.p.m. for this purpose. From each point representing the different revolutions vertical ordinates are now drawn, representing, according to the horsepower scale, the brake horsepower developed by the engine at these revolutions, and through the points so determined a motor b.hp. curve is drawn.

Next place this diagram on top of the logarithmatic diagram of the propeller, placing the origin on the base line *A* on the base line of the logarithmatic diagram with the point *A* at the speed at which it is desired to determine the brake horsepower available. The propeller efficiency, and from the latter the e.hp. available, can now be determined.

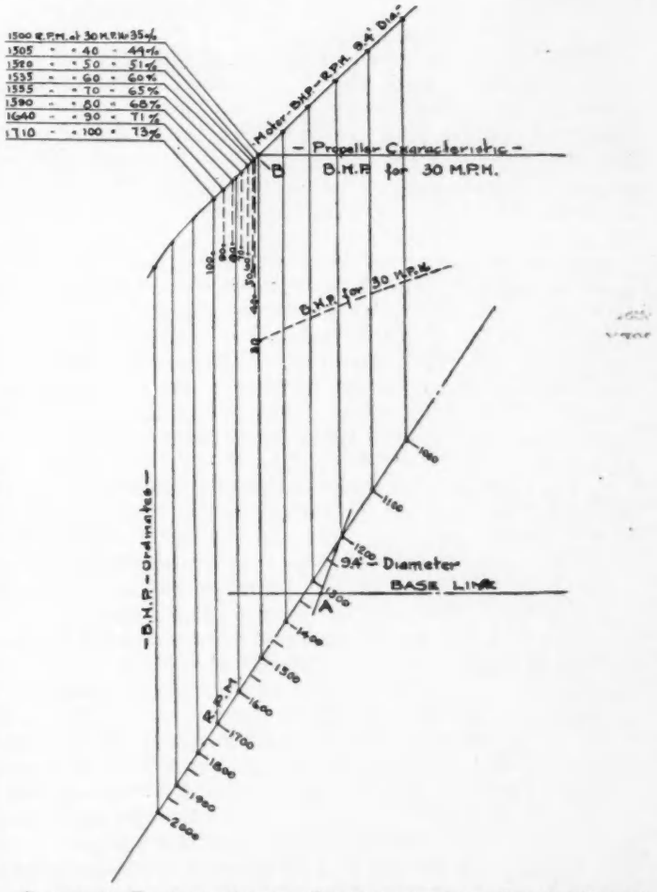


CHART FOR DETERMINING THE PERFORMANCE OF A LIBERTY ENGINE AND A DURAND NO. 8 PROPELLER

This construction is based on the fact that the horsepower absorbed by the propeller and the horsepower delivered by the engine must agree. Thus, for example, placing the point *A* at a speed of 30 miles per hr. it is found that the brake horsepower curve of the diagram intersects the propeller characteristic and the engine characteristic at a point *B*, indicating that the engine will make 1500 r.p.m and develop 355 b.hp. at this speed of advance.

By drawing a vertical line through this point of intersection of the two curves to the dotted characteristic of the same propeller, the e.hp. developed by the propeller may be determined. This can also be determined by measuring the distance on the vertical line between the full line and dotted line representing the propeller characteristics. By transferring the length of this line to the scale for efficiency, the propeller efficiency can be determined.

In this manner the brake horsepower available and the e.hp. available have been determined and are shown on the horsepower curves on page 3. It will be seen that at 30 miles per hr. the engine can only turn the propeller at 1500 r.p.m., developing 555 b.hp. Also, that at this speed the efficiency is only 35 per cent and only 124 e.hp. is available, although the engine is developing 355 b.hp.

Determining Plane Performance

Having now determined the e.hp. available, we are ready to determine the performance of the airplane. It will be noted that the lowest speed indicated in power flight is 58.5 miles per hr. Thus these two points of performance are determined.

The climbing power of the airplane with full power is determined by taking the difference of e.hp. required and e.hp. available at the particular speed at which the airplane is flown in the climb. This difference is greatest at the speed of 73 miles per hr. The climb is determined from the reserve e.hp. available, which is this case is 76. Multiplying this e.hp. by 33,000 and dividing by the weight of the airplane, assumed in the example to be 6500 lb., it is found that the initial climb should be 386 ft. per min.

Further inspection of the curves shows that the minimum horsepower is required at a speed of 62 miles per hr. It is at this speed that the airplanes should be flown to get the greatest endurance. If, however, it is desired to get the greatest range, the most favorable speed will be indicated by drawing a tangent from the origin to the e.hp. required curve, as at this point the most favorable ratio is attained between velocity and horsepower required.

In the example this speed is found to be higher than the speed for minimum power and is about 73 miles per hr. It will be noted that the tangent to the curve substantially conforms to the curve over the range of speed from 70 to 76 miles per hr. If the endeavor is being made to cover the greatest possible distance, it would be desirable to select the higher of these two speeds, for the reason that at the higher speed the controls would be more effective; the flight would be steadier and would be accomplished in a shorter time.

As the airplane proceeds its weight will be reduced because of the consumption of fuel, and with a plane of heavy carrying capacity this reduction of fuel at the end of a long flight will appreciably reduce the load and thereby decrease the horsepower required for flight.

In the example chosen, I have indicated the horsepower required when all the fuel is used up, assuming a weight at this time of 4500 lb. In this condition the most efficient speed will again be indicated by a tangent to the origin, and in the example this speed is appreciably lower than that indicated for the full load condition, being anywhere from 55 to 60 miles per hr. At intermediate stages intermediate speeds will be found the best for the greatest range. This, therefore, indicates that in planning a long-distance flight due account should be given to this effect, as the radius of flight will be appreciably increased if proper account is taken of the influence of change in weight. To be exact, the tangent should not be drawn to the e.hp. required curve, but to a set of curves which can be derived from these curves indicating the fuel consumption at different speeds and at different loads. The determination of the fuel consumption curves is a simple matter, but it would take more time and space than I consider it desirable to give in this paper. I can state, however, that the favorable speeds for long-distance cruising are not appreciably affected by using these fuel consumption curves in preference to the e.hp. required curves.

The computations made in deriving the curves shown have been based on the Liberty engine, using straight drive. If it were possible to have available the same power with the geared-down propeller, it would be possible to greatly improve the propeller efficiency and thereby to improve the performance of the airplane indicated in the example. It is unfortunate that the geared-down engine is not available for general use, as the performance of practically every plane I know of using this engine in our country would be materially improved by its use. An inspection of the $\frac{V}{ND}$ efficiency plot will make this clear. I also consider it unfortunate that in the development of the geared-down Liberty engines which have been produced, advantage has not been taken of the possibility of locating the propeller more centrally in relation to the engine group, because of the advantages which would be gained in streamlining. This engine is extremely awkward to streamline in its present form.

Design of Seaplane Floats

I will now proceed to the consideration of some of the elements of design of seaplane floats. The requirements of seaplane floats, because of the nature of their use, are necessarily conflicting, and the best that can be done is to make a compromise, bearing these in mind.

The first requirement of a float is that it shall be seaworthy. This requires that the form shall be properly proportioned to provide good initial stability and a reserve of buoyancy. This is necessary to obtain a reserve of stability, as the seaplane must float without capsizing in a sea-way and in strong winds. This requirement in itself conflicts with airworthiness and lightness and with the adoption of the best streamline form, which otherwise would be, in general, a form similar to a dirigible. It must be strong, but this naturally conflicts with lightness. It must also have good planing qualities, and this requirement conflicts with streamline form. Airworthiness requires that it should have the minimum resistance and interfere in the least possible degree with the other characteristics of the seaplane.

In order to develop the best form of hull, the Navy Department began experiments at the Washington model basin late in 1911. These experiments were initiated by Capt. W. I. Chambers, U. S. N., with a view to the use of hydroplane blades, such as had been used by

Forlanini, and to improving the planing qualities of the then existing types of floats. At that time the most successful float was that constructed by Glenn H. Curtiss, having a simple box section and a sled-form profile. At the same time Burgess had developed twin floats having a single step, which had also proved successful.

One of the earliest experiments at the model basin was an attempt to reduce the wetted surface to a minimum by the use of a semi-circular section in the form of a half-cylinder whose ends were pointed like a projectile to reduce the air and water resistance. It was fortunate that this model was tried among the first, for its trials at once showed up a factor which later was discovered to be of the greatest importance, this factor being suction, due to downward curved surfaces when exposed to the contact of water at high speeds. It was at once realized that in the test of the floats due allowance should be made to represent the change in load carried by the float as the speed of the seaplane increased and the lift of the wings became an important factor, and all runs at the model basin had been made taking account of this and determining for each particular speed the "corresponding displacement" of the float. This was originally done by counterweighting the float so that the weight resting on the water represented that which would be the case taking into account the auxiliary lifting power of the wings. In the latest form of apparatus for testing at the basin this compensation is automatically made by the use of an inclined vane submerged in the model basin, which, by means of a system of pulleys, exerts a lifting power which is proportional to the lifting power of the wings at the speed at which the test is run.

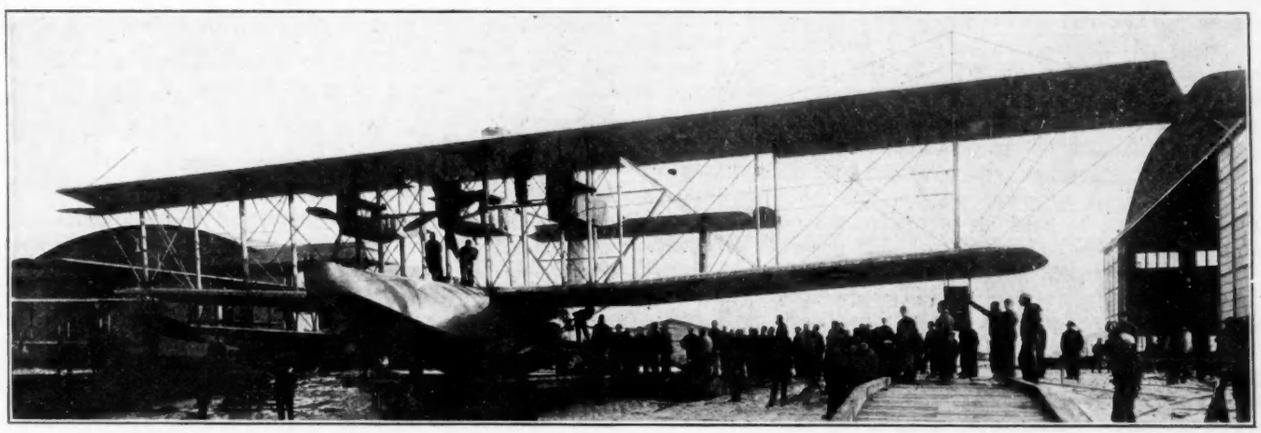
In the tests with the semi-cylindrical model above referred to, it was found, as anticipated, that the resistance at low and moderate speeds was less than that experienced with other models, but as one-half of the speed for the get away was approached, and therefore the float carried only three-quarters of the original load, it was found that the resistance of this model instead of decreasing, increased; and that the model, instead of planing, as was expected, settled into the water and, finally, at the get-away speed, with no weight being carried by the float but the float just in contact with the water, the influence of suction was so great that this model, instead of skimming the surface, proceeded to envelope itself in water and was drawn down so sharply by suction that its deck was flush with the surface of the water in the tank and great sheets of spray were lifted clear of the surface of the model basin.

As the work progressed the models of every known successful type of float were tried in the model basin, and data were collected as to the performance of these models. At the same time many experimental models were tried, and when these showed improvement over existing types, full-sized floats were constructed and tried out in actual flight. From these trials it was found that the conditions indicated in the model basin were duplicated in practice with full size, and it was seen that the model basin tests formed a means of predicting the performance of full-sized floats.

The steps of the Burgess floats were ventilated, and an investigation of this feature showed the value of ventilation for the step-type floats then in use.

All sorts of bow forms were tried and were shown to have very little influence on performance. The use of one, two, three and four steps was tried, and the indications were that there was little, if any, advantage to be gained by the use of more than two.

The introduction of the V-bottom showed promise of improvement, but it was early found that a V-bottom at the bow was invariably associated with large quantities of spray which would flow over the planes, and also, in a cross-wind would make the navigation of the seaplanes very uncomfortable. It was found by making the lines hollow at the bow that this spray could be held down close to the water, and in some later designs this hollowness was also introduced at the step, apparently with beneficial results. After much experimenting it finally became apparent that the best form of hull was that embodying the single ventilated step, in which the after bottom rose at an angle of approximately 8 deg. to the bottom just forward of the step. The reasons for this are about as follows: With this type of float sufficient buoyancy can be provided abaft the step to eliminate the necessity of tail floats for stability. It was also found that by ventilating the step the water flowing under the forward bottom flowed over the step in the form of an inverted waterfall and that the contact of this inverted stream moved further aft as the speed increased and generally passed clear of the tail of the float just before planing was attained. At this point maximum resistance was encountered. After this point was passed the float proceeded to plane on the forward step, and because of the raised position of the tail of the float, it was then possible to vary the trim of the plane and change the angle of attack without again bringing the tail of the float into the water. Then progressively as the speed increased to flying speed the planing power

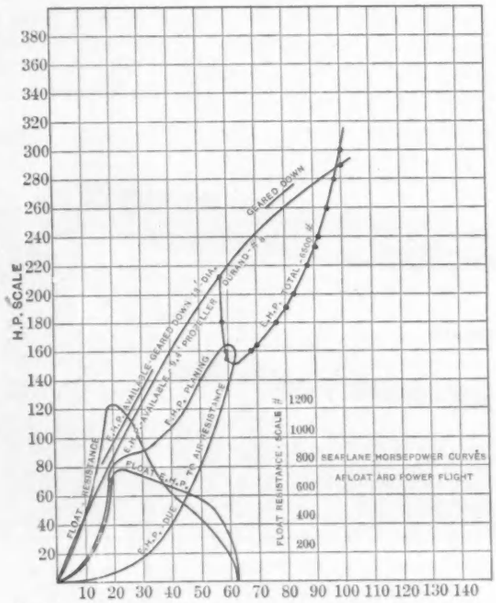


THE NC-1 SEAPLANE WHICH IS A COMPROMISE BETWEEN THE HYDROPLANE AND FLYING BOAT TYPES

of the portion forward of the step increased rapidly and the amount of wetted surface exposed to the action of the water was rapidly reduced, and the resistance of the float decreased, until finally at the get away the water resistance of the float was eliminated.

The best results are obtained where the bottom of the float just forward of the step is substantially parallel to the axis of the seaplane. This portion of the bottom should have no curvature for a distance of several feet forward of the step.

Attempts were made to curve up the portion abaft the step with a view to producing a better streamline form for the hull, but this curvature was invariably found to produce suction, retard planing, and in many cases to augment the resistance of the float to such a degree as to require an excessive reserve of horsepower in order to get away. There was one case where a flying boat was built with very moderate curvature abaft the step, but



SEAPLANE HORSEPOWER CURVES AFLOAT AND FLYING

on account of this curvature in the tail was unable to leave the water with a single passenger. Even though it could get up to a speed where the step itself was clear of the water, the tail would still drag and could not be drawn out of the water. By slightly modifying the tail of the float so that the lines abaft the step were straight, this same flying boat with the same powerplant was able to get off the water with a pilot and passenger.

One of the earliest floats tried at the model basin and built in full size was a twin float having a sharp V-bottom. The lines of this float conformed to the lines of a successful gunboat, and it was very pretty and clean in its action, but due to the influence of the curvature of the buttock lines at the stern, suction was present in this model and an airplane fitted with these floats, although able to get away with a pilot, was unable to get away with a pilot and passenger, there being insufficient reserve power to get over the hump.

Until very recently it was considered that so many inches of beam were required for every 100 lb. of weight carried by the float in order to attain planing, and this criterion has led to the adoption of the great beam found in the F-5 and H-16 and HS-2 models. But experiments with floats suited to carry 1000 lb. each indicated that this model was remarkably satisfactory. The attempt was therefore made to enlarge this model in geometrical proportion to a 2000-lb. float, and the model basin results indicated that this could be satisfactorily done. Another model was made of a 2000-lb. float and behaved satisfactorily. This same model was expanded to a 6000-lb. float, which behaved even better than the original. The lines of the N-9 float, which has proved successful in our training program, were developed from the original 1000-lb. float, although this float had less beam than the original full-size float which was unsuccessful. As a result of these trials, I now consider it to be conclusively established that once a satisfactory float is developed for carrying a definite load under given conditions, the same design can be used for larger loads by merely expanding the original lines in the ratio of the cube root of the displacement ratios.

In the design of the float for the NC-1 this principle was used and the model tested in the model basin, although only one-twelfth full size, gave data which indicated satisfactory performance. These data have been closely verified by the actual performance of the NC-1, though many designers were skeptical that this float could handle its load on so narrow a beam. This is no greater than that used in the F-5; the F-5 carries a load of only 13,000 as against over 22,000 lb. carried by the NC-1.

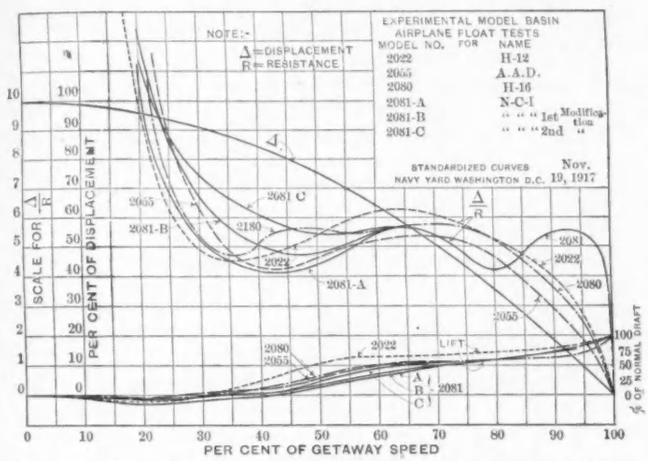
Attention is now invited to a series of curves showing the results of model basin tests on a number of different models.

Results of Model Basin Tests Compared

The dimensions of the floats and the seaplanes they represented were so different that to get a comparison it has been necessary to plot these results on non-dimensional scales. It will therefore be noted that the displacement of the hull is plotted as a per cent of the total displacement based on a per cent of the get-away speed. The resistance of these floats is indicated by a plot of the ratio of the displacement to the resistance; also, based on the per cent of the get-away speed.

Based on the plot of model No. 2022, which is that of a successful H-12 boat, I have plotted the resistance and the horsepower required to overcome this resistance for the sample seaplane, the horsepower curves of which I have already explained, and I shall return to those plots in a few minutes. Before doing so, however, I wish to invite your attention to the plots of model Nos. 2081-A, 2081-B and 2081-C. You will note that the resistance of No. 2081-A was nearly one-quarter of the displacement at 40 per cent of the get-away speed; that the resistance of No. 2081-B was reduced to nearly one-fifth of the displacement at about 47 per cent of the get-away speed, and the resistance of No. 2081-C was between one-fifth and one-sixth of the displacement at about 52 per cent of the get-away speed. Also, the displacement in the latter case is less than in the preceding cases.

This change was brought about as follows: The original form of float had two steps, with curvature in the middle step and a rank up-curvature in the rear step. No. 2081-B represents this model with the rear step straightened, and No. 2081-C represents this float with straight lines for the bottom abaft the first step. It will readily be seen that the first modification was an improvement over the original, and the second modification was a still greater improvement. These models represent the model of the NC-1, and there is no doubt in my mind that if the original model had been used this seaplane could not have got off the water. Further, the



RESULTS OF TESTS AT MODEL BASIN ON A NUMBER OF SEAPLANE FLOATS

influence of the curved portion at the tail of the float would have been so great as to cause the machine to squat so badly that the tail surfaces would have been caught in the stream of water rising from the tail of the float.

Let us now return to the horsepower curves. It will be noted that the resistance of this seaplane float reaches a maximum at a speed of 20 miles per hr., which speed corresponds to the point at which planing begins, and that there is a secondary hump at a speed of 40 miles per hr. The get-away speed is assumed as 62 miles per hr. The horsepower curve has been directly derived from the resistance of the float, and this horsepower must be compounded with that of the airplane progressing through the air. The horsepower required for this purpose is determined by taking the horsepower of the airplane at 62 miles per hr., which in this case is 150 e.hp., and noting that the horsepower for the wings and head resistance is proportional to the cube of the speed. We thus derive the curve of the total air e.hp. required for the seaplane, which must be compounded with the horsepower required for the float, thus giving us a total horsepower curve for the seaplane for speeds below the get-away speed, that is, while still in the water.

From an inspection of the horsepower curves, it will be seen that the maximum horsepower for the float is required at a speed of about 23 miles per hr., and that this, compounded with the horsepower due to air resistance, requires 88 hp. at this speed.

The horsepower for planing is very little exceeded by the horsepower available, so that it would take a relatively long time to pass through the planing condition; but, after this point is passed, the seaplane should accelerate rapidly because the reserve of horsepower available rapidly increases up to the get-away speed.

There is a secondary hump in the horsepower curve at 60 miles per hr. just before the get away is attained, but this secondary hump is of little importance as there is an ample reserve of horsepower at this point.

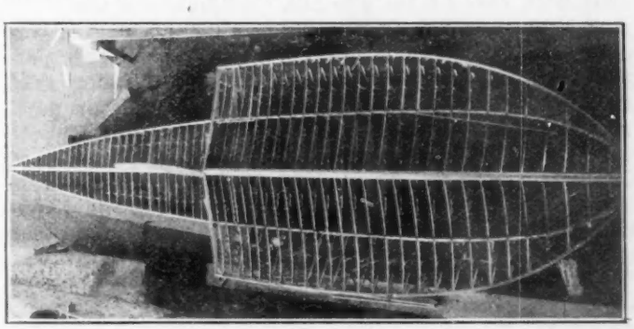
As a matter of interest, I have investigated the improvement in performance which could be expected if a geared-down engine were used, assuming a ratio of 0.6; that is, the propeller turning at 0.6 of the revolutions of the engine. With this gear ratio a propeller 13 ft. in diameter is indicated. Such a propeller at a speed of 80 miles per hr. would show an efficiency of 73 per cent as against 69 per cent for the 9-ft. diameter propeller. This gain of 4 per cent at 80 miles per hr. would increase the climb by more than 11 per cent. It would have little effect on the speed, as the horsepower curve is very steep in this region. The improvement in efficiency at 20 miles per hr., although only 6 per cent would mean an increase of 200 per cent in the reserve of horsepower to get over the hump in the horsepower curve at that speed. You will therefore see why in naval work the use of the geared-down propeller offers considerable advantage. The substitution of the geared-down Liberty for the straight-drive Liberty engines in the F-5 changes the top speed of this seaplane from 90 to 100 miles per hr. and makes the get away of this seaplane certain and rapid under all conditions, whereas the straight-drive propellers were only able to get this boat with great difficulty in a calm.

THE V-BOTTOM VERSUS THE FLAT

Experiments have recently been made at the model basin on a series of models having different angles of V-bottom from the flat bottom up to a 20-deg. V, and it is found that from a resistance point of view there is very little difference in the performance of the four models tried. So far as any advantage is shown. the deep-angle V has slightly the best of the argument. From a service point of view the deep V-bottom has many advantages; among them its remarkable shock-absorbing properties in taking care of bad landings, or in getting away and landing on a rough sea. The V-bottom also permits landing across the wind without serious retardation and without danger of capsizing sideways. This type of hull appears to absorb the shock by penetration and reduces the loads imposed on the bottom planking and on the framing supporting this. Due to this feature there is no need of carrying shock absorbers between the floats and the rest of the plane structure, and the lightest possible construction can be adopted.

The first hulls built in this country had an elaborate framework of ribs and longitudinals supporting the bottom planking, which afforded a regular network having hundreds of intersections requiring fastening, the fastenings themselves weakening the frames and the longitudinals at the point where the frames carried concentrated loads on small areas of side grain. This type of construction was unnecessarily heavy and costly and was early abandoned in the construction of pontoons of navy design in favor of the longitudinal system of support.

In the longitudinal system of support the inner ply of planking is run athwartship and thereby constitutes a continuous system of ribs. This system is further reinforced by the outer planking run 45 deg. to the keel, which also acts as a continuous system of ribs, and these two systems transmit the water pressure as a distributed loading to the longitudinal members, which do not have their strength robbed by a series of notches. The lon-



BOTTOM VIEW OF THE HULL RIBBING OF THD HS-1 TYPE SEAPLANE

gitudinals are arranged so that they collect the distributed load and concentrate it at points of support in athwartship bulkheads and these bulkheads in turn distribute the load to the keel, to the chine stringers, and to the deck planking. The keel itself is usually associated with a center longitudinal truss. Through these members the load is finally distributed to struts or directly to the wing structure.

On a large scale this system is adopted in the construction of the hull of the NC-1 which, although it embodies other features than those necessary to support the bottom planking, weighs only 2600 lb. while it carries a load of 22,000 lb. This hull has demonstrated ample strength in landing on and getting off an 8-ft. cross sea in practically dead air, where the landing and get away were both made under the hardest conditions.

A controversy has existed for years as to the merits of the single float as compared with the twin float, but, based on the experience of our Navy with examples of both types, I believe that the central float with wing tip balancing floats is decidedly the better arrangement. In the central float system the loads can be concentrated on the point of support, whereas in the twin-float system the loads are usually concentrated in the center of the span and the wing structure has to be utilized to gain the necessary stiffness and necessarily has to be made heavier. In the center-float type if a single propeller is used it is located above the float and protected from the water, whereas in the twin-float type such propeller necessarily swings over the gap between the floats, which subjects it to punishment by spray and broken water. In landing a twin-float seaplane, unless both floats arrive at the same time, the second float invariably strikes harder than the first, being slammed down on the water. Due to the greater lateral stiffness of the twin-float system, when getting off rough water the seaplane is forced to conform in its attitude to the form of the surface and wracks and lurches violently sideways unless going directly across the crest of the sea. In maneuvering in the air, also, the separation of the twin floats adds considerably to the inertia about the longitudinal axis and makes the action of the ailerons less effective. With twin floats, when taxi-ing across a strong side wind the lee float must have at least 100 per cent reserve buoyancy, and this leads to greater weight than is necessary with the single center-float providing the same stability.

Types of Navy Planes

As above referred to, the principal types of service planes used by the Navy were the HS-2, H-16 and F-5. Your attention is invited to the illustrations of these.

The HS-2 was developed from an original twin-motored seaplane designed for the Army, which, however, did not prove successful. It was originally intended to be used with two 100-hp. engines. Later, when the Navy took hold of it, the Curtiss VX3, a 200-hp. engine was used, and this seaplane gave a fairly satisfactory performance with this powerplant. At about the same time the Liberty engine became available, and as soon as it was installed it was found that this performance was very much improved and this seaplane was capable of flying at a total weight of about 5900 lb. On this basis it was then attempted to convert it into a military machine by providing the necessary guns, bombs and other equipment. After everything had been added, it was found impracticable to carry the military load desired on a limit of 5900 lb. total weight. The expedient was therefore adopted of adding wing surface, and the original HS-1 thus became the HS-2, capable of carrying a load of 6500 lb. with practically no reduction in full speed and with considerable increase in climbing power. Many forced landings have been made at sea; some due to powerplant difficulties, such as stoppage of fuel supply, or failure of the engine or propeller, and sometimes due to head winds forcing a landing on a return trip on account of exhaustion of fuel. Although many of these landings were made under bad weather conditions and in rough seas, in nearly every case landings were accomplished without serious damage to the hull.

The general arrangement of this seaplane is indicated in the illustration. The pilot and assistant pilot are seated in a cockpit just forward of the wings, from which point they have a good view for the operating of the seaplane. A radio outfit is provided just forward of the pilot. A gunner's cockpit is fitted in the bow, and this cockpit is provided with a gun ring and Lewis gun. This gunner has a very good range of fire, particularly ahead and down and on either beam; also upward and to the rear above the planes. But there are no means of firing abaft the beam, and the boat is unprotected against attack from the rear. In the gunner's cockpit are also fitted the bomb pulls and the sight for dropping the bombs, which are located under the wings just clear of the hull. On account of its undefended condition against attack from the rear, this seaplane was not used in sectors where it would be exposed to attacks by enemy aircraft, but there were many places abroad—and, of course, in this country—where no such attack was probable and where it proved particularly useful in submarine patrol and convoy work. This seaplane is also used for instruction purposes as an advance step toward handling the regular twin-motored seaplanes. The HS-2 is provided with a single Liberty engine and a pusher propeller, and has very satisfactory air maneuvering qualities.

The H-16, as you will see, was a twin-engined seaplane with a flying-boat hull, using tractor propellers. The pilot and observer are seated in a cockpit about half-way between the bow and the wings, where they have an excellent view. The H-16 was also fitted with a gunner's cockpit the same as the HS-2. In addition, a wireless operator was carried inside the hull just forward of the wings and back of the pilots. Abaft the wings an additional gun ring was fitted covering the arc of fire above and between the wings and the tail controls and to take care of the region to the rear and below the tail controls; gun mounts were also fitted, swinging on brackets through side doors in the hull. The bomb gear was operated from the forward gunner's cockpit and four bombs were carried, two under either wing. This type of boat proved very serviceable, and was a substantial copy of the same type of boat built in this country for England, differing only in minor details from those supplied to England. This boat was really a successor to the H-12, which was very similar, except that the hull of the H-12 was more like that of the HS-2 both in construction and in the form of the planing fins.

As you will note, the F-5 is very similar to the H-16, being approximately 10 per cent larger than the H-16. In addition to this increase in dimensions, which was made to afford a greater military load, it will be noted that this seaplane has balanced wing tip ailerons and also a balanced rudder. The hull form is practically identical with that of the H-16. The principal data of all three of these boats will be found in the Appendix.

A little over a year ago the Navy Department decided to build a large seaplane equipped with three Liberty engines and, after consultation, a contract was entered into with the Curtiss Aeroplane & Motor Corporation

and a design was developed, under the supervision of representatives of the Navy Department, first at the Austin Street plant of the Curtiss corporation in Buffalo and later at the Garden City plant of that company. As a result, the NC-1 was developed and built and has recently undergone trials at Rockaway Beach.

It will be noted from the illustration that this seaplane is neither a hydroplane nor a flying boat. It may be considered a compromise between these two types. The three engines are arranged as tractors in separate nacelles placed between the wings, and the pilot and assistant pilot are located in a cockpit just abaft the center motor. One gunner's cockpit is located on top of the center plane, while another is placed in the bow. The tail is of the biplane type and supported by hollow spars in an inverted pyramidal form of structure resting on the stern post of the hull. The pilot and observer have an entirely satisfactory view for general maneuvering and for landing and get away. It was contemplated that additional gunners would be placed in the after portion of the hull with guns mounted on brackets so that they could cover the arc of fire from the beam to the stern and downward; also that this seaplane would carry a number of bombs, together with a non-recoil gun

Angle of attack, deg.	$K_x \times 10{,}000$	$K_y \times 10{,}000$	K_y/K_x	W
0	0.62	4.3	6.3	6,500
2	0.65	8.5	12.2	6,500
4	0.88	12.3	13.7	6,500
6	1.20	15.5	12.6	6,500
8	1.65	18.7	11.3	6,500
10	2.06	21.6	10.5	6,500
12	2.55	24.4	9.5	6,500
14	3.30	26.4	7.8	6,500
16	4.85	27.3	5.6	6,500

of large calibre at the bow. Three more of this type are under construction, and advantage is being taken of the opportunity to make a number of changes which it is believed will improve performance over that of the original.

Future Developments

I have been asked to incorporate in this paper some remarks on the future developments for the Navy, but as these more properly come under the subject of operations of the Navy, on which subject we are to hear from Commander Towers, I shall limit my comments to the statement that the Navy Departent fully appreciates the desirability of experimenting with a view to improving existing types and the development of new types of seaplanes and airplanes, directed to the solution of those problems which have arisen in the war and, more particularly, to the development of seaplanes or airplanes for operation with the fleet. This development, as I pointed out at the beginning of this paper, was naturally set aside because at the time of the entry of the United States into the war the lines on which development was most badly needed were already pretty definitely determined and there was almost no need of airplanes for operation with the fleet. I believe that much larger seaplanes are possible and will probably be found useful for naval work, and development on these lines may reasonably be expected.

This paper has already reached too great a length for me to enter into the subject of structural design, which is a very broad subject in itself. It is a matter of interest to know that so far as this branch of aeronautic engineering is concerned, very satisfactory progress has been and is being made, and along these lines some of the greatest improvements in the near future may be expected. So far as aerodynamic engineering is concerned, wind-tunnel experiments and full-sized experiments have now brought this branch to a very satisfactory state, so that the performance of a new design can be very definitely determined, even before construction is begun. So far as the engineering features of float design are concerned, I believe important progress has been made through the demonstration that model basin data can be accurately applied to full-sized design.

Appendix

The tables appended give the calculations for the performance curves of a seaplane with a biplane arrangement of R. A. F. 6 wings and a head resistance of 20 sq. ft. In these calculations the following formulas were used:

$$T = W \div \frac{K_y}{K_x} V^2 = \frac{W}{K_y S} EHP = \frac{TV}{375}$$

W = Weight in pounds
T = Thrust in pounds
V = Velocity in miles per hour
S = Wing surface in square feet
K_x = Drift factor for biplane arrangement
K_y = Lift factor for biplane arrangement

T	K_yS	V^2	V	TV	EHP Planes
1,030	0.301	21,600	147.0	151,300	404.0
532	0.595	10,900	104.5	55,700	148.5
474	0.861	7,550	87.0	41,200	110.0
516	1.085	5,990	77.5	40,000	106 7
575	1.309	4,960	70.5	40,500	108.0
618	1.512	4,300	65.7	40,600	108.2
684	1.708	3,800	61.7	42,200	112.2
833	1.848	3,520	59.5	49,500	132.0
1,160	1.911	3,400	58.5	67,900	181.0

$EHP_h = \frac{K_y S V^2}{375}$ and is independent of the angle of attack.

$K_yS = 0.06$ and $\frac{K_yS}{375} = 0.00016$

V	V^2	EHP_h
10	1,000	0.16
20	8,000	1.28
30	27,000	4.32
40	64,000	10.24
50	125,000	20.00
60	216,000	34.60
70	343,000	55.00
80	572,000	82.00
90	729,000	116.50
100	1,000,000	160.00
120	1,728,000	276.00

$$\frac{EHP_1}{EHP_2} = \left(\frac{W_1}{W_2}\right)^{\frac{3}{2}} \quad \frac{V_1}{V_2} = \left(\frac{W_1}{W_2}\right)^{\frac{1}{2}}$$

$W_1 = 6500$ $W_2 = 4500$ $\frac{W_1}{W_2} = 1.442$

$$\left(\frac{W_1}{W_2}\right)^{\frac{1}{2}} = 1.2 \qquad \left(\frac{W_1}{W_2}\right)^{\frac{3}{2}} = 1.73$$

L	EHP_1	V_1	EHP_2	V_2
0	404.0	147.0	234.0	122.5
2	148.5	104.5	86.0	87.0
4	110.0	87.0	68.5	72.5
6	106.7	77.5	61.5	64.5
8	108.0	70.5	62.4	58.8
10	108.2	65.7	62.5	54.8
12	112.2	61.7	65.0	51.5
14	132.0	59.5	76.3	49.6
16	181.0	58.5	104.6	48.8

The float EHP for an H-12 seaplane weighing 6500 lb. and having a get-away speed of 62 miles per hr. is given below for varying percentages of the get-away speed.

Per cent of Get-away Speed	V	△, per cent	△, lb.	△/R	R	RV	EHP
10	6.2	99.00	6,430				
20	12.4	95.70	6,220	9.80	635	7,880	21.0
30	18.6	91.00	5,910	4.90	1,205	22,400	59.8
40	24.8	84.00	5,460	4.65	1,172	29,100	77.7
50	31.0	75.00	4,870	5.40	903	27,100	72.3
60	37.2	64.00	4,150	6.15	675	25,100	67.0
70	43.4	51.00	3,310	6.10	543	23,600	63.0
80	49.6	36.00	2,340	5.30	442	21,800	58.2
90	55.8	19.00	1,235	4.00	309	17,300	46.2
100	62.0	0.00	0				

DATA ON DIFFERENT TYPES OF FLYING BOATS

	HS-2-L	H-16	F5-L	NC-1
Weight, fully loaded, lb.	6,432	10,900	13,000	22,000
Useful load, lb.	2,132	3,500	4,750	7,750
Maximum speed, miles per hr.	91	95	87	81[2]
Minimum speed, miles per hr.	55	56	57	61[3]
Initial climb, ft.	2,500 to 3,000 in 10 min.	3,000 in 10 min.	2,625 in 10 min.	1,050[4] in 5 min.
Over-all span, ft.-in.	74 0 19/32	95 0 13/16	103 9 1/4	126 0
Over-all length, ft.-in.	38 5 15/16	46 1 15/32	49 3 11/16	68 2 29/32
Over-all height, ft.-in.	14 7 1/4	17 8 5/8	18 9 1/4	24 6
Chord, ft.-in.	6 3 5/32	7 0 49/64	8 0	12 0
Wing area, sq. ft.	803	1,164	1,397	2,380
Hull length, ft.-in.	34 3	42 3	....	44 7

[2]Carrying a load of 21,560 lb.
[3]Carrying a load of 21,569 lb.
[4]At a speed of 67 miles per hr. with a load of 21,318 lb.

The Discussion

GROVER C. LOENING:—An interesting point that appears from the tables is that in the case of the HS-2 for example the machine in flight weighs something like 18 lb. per hp. and yet with this high load has a high speed of 91 miles per hr. An equally high efficiency is true of the NC-1 and indicates quite contrary to general belief that the aerodynamic efficiency of the U. S. Navy flying boat design is every bit as good as the fast land scouts, based on the criterion of pounds per horsepower. What is true of the small machine in increasing its performance by the refinement of design should be equally true of a large machine like the NC-1, and it would be interesting to have some information on the possible increase in load carrying and speed merely by eliminating many of the struts and wires still present in this type of craft. The paper presents briefly the usual accepted comparisons of the monoplane, biplane and triplane, with the indication that the biplane and triplane are necessary for large lifting power and in large size due to the structural difficulties of monoplane types, even admitting their higher efficiency. From work already done on the monoplane type with rigid bracing, I do not agree with this point of view and feel that study and effort applied to the large monoplane would give some astonishing results in the improvement of speed range. Neither have I been able to find any greater structural limitations to the size of monoplanes than are found in other types of machines.

CAPT. W. I. CHAMBERS:—As to the most serviceable seaplane type at present, I can conceive of the serviceability of the following general outline: (1) One middle float entirely enclosed, without cockpits, machinery or cargo capacity; (2) a short middle fuselage located above the middle float, with engine, pusher propeller, cargo space and forward gun mount; (3) two wing fuselages, forming supports for the tail, *a la Caproni*, each with engine tractor propeller and rear gun mounts; (4) two smaller wing floats for balancing purposes, not at the wing tips, but located under the tractor propellers of the wing fuselages; (5) the tail planes comparatively near the main ones and rigged so that they may be utilized, in a fixed position, to afford inherent stability on long steady flights and yet be capable of mobility in response to any demands for quick maneuvering. While I do not suggest any finality as to model or type of either powerplant or rig of the planes, I do not hesitate to predict, however, that future modification and improvement will depend more upon further improvement of the powerplant than on any other factor. Great improvements in this part of the aircraft are due, and each decisive step will result in a modification of airplane types for each specific purpose.

ORVILLE WRIGHT:—Commander Richardson's figures for the performance of propellers are based on tables derived from experiments with models. The trouble with tables of this kind comes from the fact that it is most difficult to determine the exact value of each of the factors which play a part in the propeller's efficiency. The tests are made with several variable factors, so that the measurements secured really show the result of the sum of these variables. The exact value of each one is not determined. I am of the opinion that much closer calculations can be had from a theoretical consideration of the reactions that must take place in a propeller. Commander Richardson finds that a propeller 9.4 ft. in diameter, driven by a Liberty engine, turning at 1600 r.p.m. and developing 380 b.hp., in traveling forward at a speed of 80 miles per hr., would have an efficiency of 69 per cent, or a loss of only 31 per cent. I believe it can be shown that the loss from slip alone, without considering any of the other losses, which also would be great, would be more than the amount he has found.

When the thrust is known the slip can be determined easily, because slip is merely the acceleration imparted to a mass of air by the impact of the propeller blades. Slip, therefore, must be equal to $V = \sqrt{2gh}$, in which V is the velocity; g, gravity or 32.17 ft. per sec; h, head or pressure. Air at sea level may be considered as weighing 0.0762 lb. per cu. ft. or 13.123 cu. ft. of air weighs 1 lb. Hence a pressure of 1 lb. per sq. ft. would accelerate air at sea level to a velocity equal to

$$\sqrt{2 \times 32.17 \times 13.123} \text{ ft. per sec.}$$

But it is well known that the rate of acceleration is di-

rectly proportional to the force and inversely proportional to the mass. Therefore acceleration will be proportional to the pressure divided by the volume of air. The pressure of 1 lb. per sq. ft. will accelerate 844 cu. ft. of air to a velocity of 1 ft. per sec. or 1 cu. ft. of air to 844 ft. per sec. The acceleration imparted to any other number of cubic feet of air can be expressed by the formula

$$\text{Acceleration} = \frac{844 \times \text{pressure in lb. per sq. ft.}}{\text{Cu. ft. of air acted on}}$$

The number of cubic feet of air acted on per square foot of disk area of a propeller is equal to the distance the propeller moves forward plus the acceleration or slip of the air acted on. Therefore

$$\text{Slip} = \frac{844 \times \text{thrust in lb. per sq. ft. of disk area}}{\text{Advance in ft.} + \text{slip in ft.}}$$

If the propeller considered by Commander Richardson had an efficiency of 69 per cent at 80 miles per hr. it would have a thrust of 1229 lb. Therefore the thrust would be 17.72 lb. per sq. ft. of disk area. In the formula for slip just given, substituting 17.72 for the thrust in lb. per sq. ft. of disk area, and 117.28 for the advance, we find the slip equals 76.96 ft., a loss of 39.62 per cent. It is therefore evident that it would be impossible to secure an efficiency of 69 per cent with any propeller of 9.4-ft. diameter consuming 380 hp. while advancing 80 miles per hr. I have made a rough calculation of the performance such a propeller should give, based upon the propeller being considered merely as airfoils traveling in a spiral course. A propeller 9.4 ft. in diameter working under the conditions stated would have a thrust of approximately 930 lb.; the slip would amount to 35 per cent of the total amount of air the propeller traveled through, and the efficiency of the angle of advance would be 80 per cent. The total efficiency would therefore be 0.65 x 0.80 or 52 per cent.

Commander Richardson uses a method of calculating the rate of climb of an airplane which seems of doubtful value. He makes no allowance, so far as I can see, for the extra loss in efficiency of a propeller when climbing. The thrust in climbing must be approximately equal to the thrust when flying at the same speed on a horizontal course plus the total weight of the machine multiplied by the sine of the angle of climb. It is apparent that if the machine were to climb in a vertical course the propeller thrust would necessarily have to be equal to the entire load of the machine. On an inclined course the propeller would have to bear a proportion of the entire load plus the thrust necessary to give the machine the desired speed. When climbing, the propeller efficiency is especially low in small-diameter propellers, because on account of the extra load imposed, the slip becomes excessive.

COMMANDER RICHARDSON:—A great amount of theoretical work has been done on propellers, taking it from all points of view, but in my opinion none of these methods of analysis are as satisfactory as the wind-tunnel methods, because even the theoretical investigations require the use of coefficients which must be developed from experience or practice. And I believe that when a propeller shows 59 per cent efficiency in a wind-tunnel test, where the quantities can be actually measured, that this is the real efficiency of the propeller in question under the conditions of the test, and no amount of mathematical or theoretical investigation will convince me to the contrary. The airplane horsepower required curve shows the horsepower required to propel the plant at any angle of attack, and this is relative to the air and regardless of the path of the plane. The horsepower available depends on the characteristics of the powerplant, including the engine and propeller and, as I clearly demonstrated, the propeller efficiency is a function of the speed of advance or the quantity V/ND. The curve of horsepower required, therefore, shows at any particular speed of advance of the airplane the actual horsepower effectively delivered by the propeller, and the difference between the power required to propel the plane and the actual power available is available for lifting. The brake horsepower required of course is much greater, but in the computation of the horsepower available the effects of the reduced speed in the climb are taken care of. The propeller chosen for the example was selected for the purpose of illustration and not because it was the most efficient possible. Both Eiffel's and Durand's experiments have shown that efficiencies as high as 80 per cent are entirely possible.

I am glad to note that Mr. Loening considers that his monoplane type of structure can be developed to take care of great loads. I have not personally investigated the possibilities of such a structure for heavy-load carrying, and I may be conservative in assuming that when great loads are to be carried it will be found that the conventional truss arrangement of the biplane structure will be found more economical as to weight of structure and equally efficient aerodynamically where proper care is used in streamlining all the elements involved.

U. S. EMPLOYMENT SERVICE TO CONTINUE

ALTHOUGH the failure of Congress to appropriate funds for the continuance of the U. S. Employment Service has made it necessary to discontinue the activities of the Professional and Special Section, the work of the Service will be carried on through the various offices which are still open. These offices will handle the placing of technical men who are leaving the Army and the Navy as well as supply other classes of workers.

In the eight weeks ended Feb. 22, the Service received 1,090,124 applications from persons seeking employment, of which 930,029 were referred to opportunities and 679,513 were reported placed in employment. The difference between the number referred to positions and the number reported placed, it is explained, is due in a large measure to the failure of either the employe or employer to send in the return cards. Unless these are received the Service, of course, has no record of whether the prospect has obtained employment or not. The largest week was the one ended Jan. 11, when 163,131 applications were received and 105,748 applicants placed. Since that time the number of applications, persons referred to positions and those receiving employment has declined with the exception of the week ended Feb. 1, when there was a marked increase in the number of applicants placed over the preceding week.

Addresses at Kansas City Dinner

FOLLOWING the afternoon session of the Tractor Meeting at Kansas City on Feb. 27, a dinner was held at the Hotel Baltimore which was attended by 270 members and their guests. Finley P. Mount acted as toastmaster. The other speakers of the evening were Edward A. Johnston, Joseph E. Pogue, J. B. Bartholomew and David Beecroft.

ADDRESS OF FINLEY P. MOUNT

IT would seem that among the many problems which a tractor designer should keep in mind the first is the use to which his product is to be applied. If you are about to design a tractor I respectfully suggest that the first question you should ask be: What is it expected to do; what kind of work is it to perform and what economies can be secured by the performance of that work with a power machine? The work of a tractor has become synonymous with farm work and, since the farm tractor is to be bought and used by the farmer, we should first know just what this work is, we must take a look over the entire farm for a year, and analyze and classify the work that can be done by mechanical power. We must also broaden our views geographically to cover the whole field of farming and include not only the one-purpose farm as found in the vast small-grain areas of the West, but the general-purpose farm with its diversity of crops and consequent diversity of work.

To my mind farm work divides itself, from the standpoint of a farm tractor, into three classes:

(1) Heavy-duty work, such as breaking ground, preparing the seed bed, drawing heavy loads, operating the haying and harvesting machinery in large or multiple units, pulling a grain separator, and the like.

(2) Light-duty work, such as cultivating row crops, operating haying tools and harvesting machinery in single units, and doing all the light jobs on a farm ordinarily performed by from one to three horses.

(3) Transportation over improved roads between the farm and the market of supplies to and products from the farm.

In my judgment an all-purpose farm tractor, one to do well all the work on a farm, is a fundamental impossibility. It may be admitted in the outset that all of these farm jobs might be shot at by one type of tractor, but this cannot be done economically. The motorized farm will become a reality only when tractor engineers and manufacturers realize that it is not only worth while but an economic necessity to provide the farmer with a power unit for each class of work. One does not attempt to haul logs in a buggy, or drive to church on Sunday in a log wagon. The first is wholly impracticable and both would be uneconomical. Railroading is a big business, but not as big as farming; its problems of power are less intricate than the problems of power farming; yet it was not long before the pioneer railroads discarded the all-purpose locomotive, classified the work and built their power units accordingly.

Breaking ground and belt operations are the heaviest parts of farm work. To do this work successfully and economically the tractor must have excess power in its engine to meet readily and without strain the highest peaks of requirement in the way of heavy gumbo soils, hard dry-packed soil conditions, and varying grades of work.

The machine must be built to operate with perfect ease all the belt-driven machinery which any farmer may have occasion to use.

Too much cannot be said in favor of excess or reserve power in a farm tractor. The farmer has shown a natural tendency to overload his tractor. I believe that more troubles have arisen in the field on this account than from any other reason. Having started with such an engine, the transmission, frame, wheels and all supporting parts of the tractor proper, must be of such proportions that the engine will not tear them down under strain. Tractor engineers and designers should always bear in mind that there is no such thing as a constant load factor in breaking ground. The strains and added loads in plowing come suddenly, intermittently and everlastingly, and are superimposed on the ordinary load due to the draft of the plows pulled on level ground, in ordinary soil, at ordinary depths. It is the difference between a steady pull and a succession of jerks or blows. One may, of course, have whole areas or whole seasons when the load factor in plowing is practically constant and steady, but these areas and seasons go without rule and are likely to change during one month, in the same township, on the same farm. The designer who would succeed must meet the hardest rather than the easiest conditions. Finally, the whole machine must be heavy enough to give required traction. Lugs or grouters alone will not give it. Lightness is not the sole desideratum. When an engine will spin the well-groutered wheels of the tractor on which it is mounted, that tractor is as light as it ought to be.

Having produced the tractor that will do the work intended efficiently, there remains the big factor of economy. This does not mean fuel economy alone, but includes as well the answer to the questions: How long will the tractor stand up? How many seasons is it good for? How many plow-miles will it produce? On these points our knowledge is largely empirical.

There are certain elements which I believe are essential in a tractor for this class of work. These are slow speed heavy-duty engines, two-cylinder type preferred; the fuel combination of oil, air and water so automatically controlled as to meet instantly each new condition of load; a spur-gear transmission mounted on the tractor frame, and wheels sufficiently strong and rugged to take all the strain put upon them by the engine without undue wear or breakage. The question of fuel economy is of course an important one. Tractors can be made which produce as much power on a gallon of kerosene as on a gallon of gasoline. Such tractors have been built and have been doing this for years, and since the cost of kerosene is ordinarily not over one-half the cost of gasoline, it is obvious that kerosene is the logical fuel for a farm tractor. A fuel cost of 45 cents per acre plowed is no uncommon performance. On this basis the plowing of 300 acres per year would amount to a saving of $135, and in a life of 10 yr. the saving would equal the entire cost of many tractors capable of doing this amount of work.

Our own experience has proved to us that this type of engine and tractor is economical in both fuel consumption and length of service. Admittedly this type of en-

gine costs more to manufacture than a multiple-cylinder, high-speed engine of equal horsepower.

If tractor engineers, therefore, can design and build a farm tractor for heavy-duty work along the lines of the automobile type of construction and design, one which will in fact stand up, take the rough and tumble knocks and fights it will be subjected to, under all conditions of soil, seasons and service, and show actual length of life under these conditions and reasonable fuel economy, they will be conferring a real benefit on the industry as a whole. Scientific designing may produce such a tractor, but science can never be certain nor can it prove in advance of actual tests and length of service, that such a type of machine will be efficient and economical.

You can calculate to a nicety the strength of materials required for a railroad bridge; you can build a locomotive with a narrow margin of safety, you can design an automobile, and even build an airplane with correct provision for results, because you are dealing with factors known and reasonably within your control; but when you begin on a tool to dig into mother earth, you open up a field that is difficult of advance conjecture.

The second class of farm work which can be economically performed with mechanical power is a much simpler proposition. Here the light work of pulling a planter, a row crop cultivator, a single unit of haying or harvesting tools and the like, requires neither as much power in the engine nor as much strength or weight in the tractor as a whole. This type of machine could be designed to operate from the driver's seat on the tool drawn. The tractor must be light in weight and have high clearance because of its use in cultivating corn. Here because of the small amount of power required, fuel economy itself is of less consequence. Undoubtedly a lighter and higher-speed engine can be economically used on this type of machine. Because of the speeds which may be required of this tractor, and its general lightness in weight, spring mounting would not be out of order. Of course, when you leave the corn and cotton country and try to meet the requirements of the orchard, you must be prepared for further modifications in type.

The third and last job on the farm for mechanical power is transportation over roads. Here many new factors arise and the economy due to speed alone becomes more important than in either of the other types. Moreover, the character of the roads is perhaps the greatest determining factor. The tractor which operates on the farm in doing the plowing and cultivating jobs must be geared at a speed too low to afford economy as a transportation medium. If you add a high-speed gear to it to economize in time, you shorten the life of the machine. If the attempt be made to make up for lack of speed by increasing the load hauled, the necessary cleat or grouter equipment on the wheels of the tractor will be destructive to the roads, and will prevent the general use of farm tractors on good roads for such purposes. I do not believe the heavy-duty plowing tractor or the light-duty cultivating tractor will ever take the place of a light truck for road transportation. This type of machine is now pretty well standardized and needs no comment from a tractor manufacturer.

To the objection that this method of supplying power for the farm would require an investment in three different power units, my reply is that they will entirely supplant the horse on the farm. Their initial cost, though somewhat in excess of the initial cost of the horses they replace, will be more than offset by the saving in tractor fuel over animal fodder, and the life of the tractor should be as great or even greater than that of the horse, while the saving in man-power effected, and the increase in crop production made available by the use of the tractor, remain to the operator or owner as clear profit.

There are several potent reasons why the farmer should use machine power. First, of course, is the shortage of help, which promises to become worse rather than better; second, land is becoming so valuable and will soon carry such high taxes that no man can afford to own it unless he farms it most intensively to get the greatest yield possible; he can no longer afford to devote a material part of his acreage to raising roughage and grain for horses. Finally, the food complication is not over; in fact, it has hardly begun. It will take years to get the food supply of the world back into balance, as in pre-war times, and by the time the effect of this war's destruction is ended, the added population of the world, increasing in greater ratio than food production, will create a demand that will require the American farmer to do his utmost for many years to come.

One other factor, it seems to me, is well worth the attention of the tractor designer, because it so directly affects both the manufacturer and the farmer, and that is the cost of the machine. Much can undoubtedly be done to improve the design of the tractor from a manufacturing point of view, and the methods of manufacture themselves, to lower greatly the cost of the machine without in the least detracting from its efficiency, economy or life. However, no tractor should be designed with a view to cost alone. Experience thus far has confirmed us in the belief that a cheap tractor is the dearest in the long run.

Upon these broad lines of development we can surely all lay aside our personal feelings and cooperate fully to the end that the farm tractor shall soon reach a reasonable stage of perfection and power farming take its rightful place in the business world alongside the other great human enterprises.

ADDRESS OF EDWARD A. JOHNSTON

MOST of us here are seriously interested in designing, manufacturing and selling tractors which will be satisfactory for the use for which they are intended. Our success, in my judgment, will be equal only to our ability to make them reliable, durable and efficient.

The tractor must be reliable. The period during which the farmer does his plowing, planting, harvesting and other work connected with the crops is limited; consequently his power plant must be reliable in the average operator's hands, and operate under any and all conditions.

The tractor must be durable. It must stand up well under the heavy duty of plowing, harrowing and harvesting without too frequent delays for repairs, adjustments, etc., as these result in high operating costs.

The tractor must be efficient. The farmer who buys a tractor is not interested in the sort of efficiency that will save him $1 in fuel and cost him many times that amount in delay, maintenance, etc. Farming is a business like any other business. The farmer works for profit, and he will use the tractor only when he finds it is profitable to do so. He is not particularly interested in the number of its wheels. He does not care whether it has two or four cylinders, a horizontal or a vertical engine. He is interested only in getting a tractor with which he can carry on his farming operations and get results.

We must of course have standards as far as is practicable, but this need not be overdone. Standard belt speeds, drawbar ratings, tractor speeds, etc., will be use-

ful, and in addition to these there are many automobile and truck standards applicable to the tractor which will result in enormous saving to both farmer and the manufacturer.

We all have our pet theories and personal interests, but at the same time we are all interested in the successful development of the tractor. Any machine placed on the market and sold that does not prove satisfactory is a detriment to the tractor business as a whole. It is to our common interest to cooperate unselfishly to the fullest possible extent in producing tractors that will be satisfactory to their purchasers. There is much to be done to improve ignition, carburetion, lubrication, etc. Let us put forth our best efforts to design and manufacture tractors that are reliable, durable and efficient.

ADDRESS OF JOSEPH E. POGUE

MECHANICAL tillage constitutes a third of the food problem, but an important third. The horse and the mule are destined to pass in large measure. They represent an internal-combustion engine consuming high-priced fuel useful otherwise as food, running 24 hr. per day whether used or not, and low geared, with a capacity at best only 3 to 4 miles per hr. In place of the horse and the mule comes the tractor. The tractor for farm use is a recent development and the growth in its utilization during the past few years, especially in the Middle West, has been great.

Coming into play at a time when the national food problem has taken on a world-wide aspect, the tractor assumes the utmost present importance, while the future calls for an extension in its use such as can be expected to largely relegate to the past the old-fashioned methods of hand-power and horse-power tillage. Indeed, upon the growing use of mechanical power upon the farm by means of the tractor, the motor truck, the stationary engine and the automobile—all dependent upon a cheap and adequate supply of engine fuel—the food supply of the future turns.

Farm work must be made more agreeable and more efficient if an increasing population is to be fed. Fertilizers and tractors under organized cooperative effort spell the solution to the food problem. The adequate development of tractors would appear to depend primarily upon two factors; the growth of cooperative farming and the cost of tractor fuel. If fuel prices rise unduly, the cost of tractor operation will limit the possibilities of tractor utilization.

Tractor design is still in its formative period. Its engine and its carburetion system are still in flux. The tractor can select its own fuel. It is vitally important that tractor evolution should follow the path leading to maximum fuel economy. Now is the time to determine this matter. Shall it be gasoline or kerosene or a mixture of the two? Distillate or alcohol? Shall it be a gasoline engine or a Diesel engine, or else an intermediate type? I cannot answer these questions at the present moment, but I believe that they will be answered after further study is given to this issue. It can be said, without undue exaggeration, that the whole tractor future hangs upon a happy selection of fuel by the tractor industry. It would appear, however, that tractors, along with automobiles and motor trucks, must work in the direction of using a less specialized fuel than at present, gasoline or kerosene, and at the same time develop a greater degree of fuel economy than at present. If the automotive apparatus can adapt itself to this end, it will mean that the fuel of the future will be provided at a lower production cost, which means a lower price, than if the automotive apparatus holds out for its present low standards of fuel economy and highly specialized requirements as to fuel.

There are two problems which stand out in this connection, or rather two conditions which create these problems. In the first place, it is much easier to standardize the automotive apparatus than it is to standardize fuel. This means that if the automotive apparatus is rigidly standardized, as it must be, fuel will periodically tend to get out of adjustment with the apparatus. That is to be expected. In the second place, the automotive industry is growing more rapidly than means in sight are developing for providing engine fuel. This leads to the presumption that a shortage, or let me say an engine-fuel stress, may ultimately be expected, reflected in a rapid rise in fuel price. Both of these problems can be solved; but not without the active participation of the automotive industry, which includes, of course, the three major branches of automobiles, motor trucks and tractors.

In conclusion, then, an analysis of the fuel situation seems to show that in the future an engine fuel at favorable prices will be forthcoming if the automotive industry works toward greater thermal efficiency and shapes its development so as to handle a less specialized fuel than it is handling now.

ADDRESS OF J. B. BARTHOLOMEW

THE situation as I see it from the business side is like this. There will be no going back. I have heard a good many people use the phrase "When we get back to normal conditions." I think there are many who have thought we would drop back very suddenly in the year 1919 to normal conditions or at least to conditions as they were before the beginning of the war. We are now approaching the opening of the season. The rush is soon to be on, but I do not believe you are going to have what is referred to as "normal conditions" for a good while. The dealer and the farmer who are waiting for that will be disappointed. The farmer will wait until he is ready to use his tractor and then may not get it. The dealer who is holding off is losing his opportunity. This has been my belief for some time past; but if I am mistaken, if we do revert to something like past conditions, there is no reason why we should hold back now. Things should go ahead. We may have to go through a few seasons with rather narrow margins, but we shall not be any better off by simply sitting idle and doing nothing.

Much has been said about who is to be the ultimate dealer to handle tractors. This is no time to argue over the question whether the tractor trade belongs to the automobile dealer or the old-line machinery dealer. No matter where the tractor dealer comes from, what enterprise he may leave for this field, whether he has ever had any business experience before, I believe it will not be more than 5 yr. before the selling of agricultural implements will be divided into two very distinct sections, one under control of the hardware or horse-drawn implement dealers and the other under the tractor and tractor-drawn implement dealers. Occasionally one dealer may be big enough to cover both fields, but he will separate the two lines very sharply while managing both.

The tractor and tractor-drawn implement industry is going to be very interesting. It will undoubtedly be very fast, and will require special organization, new methods and training for a large amount of work in the fields. The old lines of horse-drawn implements and hardware will be carried on more or less as they have been, with perhaps a little canvassing in the country, but the bulk of the business will be done at the store.

ADDRESS OF DAVID BEECROFT

FIFTEEN of us were invited to the other side as guests of the British and French governments to reestablish relationships in the business world. During the period of the war the censorship and the restrictions due to the war had built up barriers.

We went through the great area of Chateau Thierry and to Rheims and Soissons. In the city of Rheims we got a vivid idea of what the Germans had done. They had been on the outskirts of the place since 1914. It had been a beautiful city of homes set on a great plain in the midst of vineyards, the houses set back in green yards with ornamental fences and great posts along the front. The posts are gone, the homes are destroyed. Into the great cathedral the Germans are said to have dropped a shell every day. The French say the Huns used it as a target for their artillerymen. We were glad to find that the pillars stand uninjured. There are great holes in the roof, the exterior is all destroyed, but the great structure still stands.

The wine cellars at Rheims are now one great underground system and at one time there were 60,000 soldiers in them. They stretched barbed wire across the passages and entrances; the machine guns were still in position on their mounts and the beds of the soldiers still in place. Then we realized how it was that the Germans, although they got to the very outskirts of the city, were never able to reach its center. They say that if Rheims had ever been taken, the final fight would have been in those great caves so far under ground.

Verdun is the immortal battle ground of Europe. The French are glad to tell how it has been a great citadel since the days of the Romans; how it is one of the great bastions that protect the front. In this citadel they kept 60,000 troops, and baked all the bread for the men out in the trenches. They could take the provisions and men out to the trenches and bring back the wounded and the ones on relief protected from shell fire.

We went from there out under the hills into Fort Deulemont and Fort Vaux. The latter is on the edge of the hills, and, as you will remember, held out wonderfully in the fight of 1916. The great drive on Verdun started on Feb. 21 and the Germans took Fort Deulemont in a few days, but Fort Vaux, which is not over a mile away, they did not get until about June 23. That tells the story of the 500,000 Hun and the innumerable French dead. When we got into this fort we found hills again, and in these were great ramifications of arcades. We saw the guns 60 ft. below the surface, and up on top of these great craters, one 40 ft. deep, but still the masonry underneath had not been reached and was uninjured. They say that Fort Vaux would never have surrendered had provisions not run out.

Then we went to the city of Arras where the British made the wonderful fight against the Germans. Here they tell another story of how they used the underground system. Arras is built on a white chalk hill, and the buildings are made from stone excavated from beneath the city. The result is that under the entire city are cellars which had never been used. In the early days of the war the British moved all their soldiers into those places, and, breaking down the walls between one building and another, connected and fitted them up. When the Germans got to the market place in the center of the city, 20,000 British troops were but a few yards away from them and were able to drive them out. While the place was not entirely destroyed, not a soul is living in the houses now.

Our hosts were anxious that we should see some examples of Hun warfare. One city, Douai, was never bombarded; it passed into the hands of the Germans in 1914, and they held it until September, 1918, living there with the citizens. In September an order came for the civil population to move out. Two weeks later the Germans had to move out. I will give you one example of what was to be seen all over the city. We went into one home, the home of a doctor. It was a typical fine home of Douai. This doctor, all during the period from 1914 up to September, 1918, had been in charge of Red Cross work under the instructions of the Germans. We saw on the door the Red Cross insignia and the official orders. He had lived there with his wife and children, and the head of the German Red Cross had lived with them. When this doctor came back to his home, this is what he found. In that beautiful house everything was destroyed. It was a five-story building with front and rear parlors. Every picture, and he had many fine ones, was cut out of its frame. The frames were thrown over into a corner. In the parlor he had a beautiful carved table; an axe had split the top in several places. There was not a piece of furniture left whole. The backs or legs of chairs were broken; the buffet in the dining room with heavily carved doors had both the doors split. The fine carved mantlepiece was marred as if struck by an axe. We went up to the bedrooms and found the bedclothing all gone, the fabric had been cut off the mattresses, and feathers were strewn over the rooms 7 or 8 in. deep. All the drawers had been pulled out of the dressers and upset in the middle of the room, and in most cases the fronts of the drawers were broken. The window shades were gone, and we could see how the draperies and poles had been pulled down. We went through every room in that home, and there was nothing but desolation and destruction; and in the fifteen or twenty other homes that we saw it was the same. In a little butcher store at the corner of the canal they had split the wooden box in which he had kept his meat; also the counters; the meat block in the center was upset and the legs broken. There was nothing in that humble shop that was not destroyed.

Some of you no doubt remember the story that Private Peat told in this country a year ago. He asked a German officer whom he had taken prisoner why they had cut down the trees, maimed the children, destroyed the homes and everything else possible. His answer was, "Oh, that's quite natural. When we retreat over an area we leave nothing. We leave no tree that can be used as an observation post, or a shelter or other point of vantage. We leave no house that will shelter anyone. We leave nothing."

In Lens not a building is standing where there had been a city of 30,000 people. On either side of the road we passed every half mile the great coal mines. There were steel structures and wrecked buildings all along the way, and although the homes were not destroyed, every door had been taken off and the framework of the windows taken out.

We went along roads where there were machine-gun locations of heavy reinforced concrete, with the familiar little loopholes for the gun every 20 or 30 ft. Some of the churches were without roofs, but all the pillars were standing in perfect shape. Occasionally one is used as a hospital.

I think we must all feel that although the armistice is signed and peace will soon be made, our work in this war is not ended.

DE GUIDE & CRIPPER

Commercial Future of Airplanes from an Engineer's Standpoint

By C. H. Day, (*Member*)

Aeronautic Meeting Paper

THE earliest attempt at a heavier-than-air machine, which we find reference to, is that of Archytas, a philosopher of Taranto, who lived about 400 B. C. The first man to whom we are indebted for approximation to the true principles, as known and written of, by himself, is Roger Bacon, an Englishman, born at Ilchester, 1214 A. D. His great wisdom seems even more marvelous in these days, since within the past century we have realized many of the ideas set forth by him. The flying machine, or means of mechanical flight, which has since made great strides, was written of and investigated by him. The art of mechanical flight, or at least the method by which it has been accomplished, seems to have been well understood by him.

Of those who have been mentioned, however, none has left us so much tangible information as has the artist, Leonardo da Vinci, the noted painter and sculptor, who was born near Florence in 1452. Besides being a great artist in painting and sculpture, he was equally as good a mathematician and engineer. His calculations, drawings and his deductions based on flights of birds, about which he has written considerable, are nearly modern in their accuracy.

Beginnings of Present-Day Machines

The flying machine, as we know it today, had its real beginning in the year 1810, with the experiments of Sir George Cayley, who analyzed the mechanics of flight and conducted experiments with gliders and spent his time experimenting with surfaces to determine their relative lifting effect when set at various angles of attack. He was also the first to suggest the use of a tail as a means of longitudinal stability and to show how the pivoting of the tail would enable it to be used as an elevator.

Following this, Henson was the next to devote much time and energy to the constructon of an airplane. He made use of much of the data worked out by Sir George Cayley. His machine, which was not built until 1843, was invented in 1835. It was a typical example of the monoplane construction as employed today, and among other things that are worthy of mention are the hollow wooden struts which he used, and double surface wings, method of tightening wires and landing wheels; he was probably the first to use a vertical rudder for lateral directional control. This machine was designed to be driven by a steam engine, which drove two propellers extending to the rear of the wings.

In 1864 we are told that Wilhelm Kress of Vienna, Austria, commenced to experiment with small models as well as propellers and in that year he built a model about 3 ft. across the wing tips and after many experiments and tests finally constructed a model in 1877, which was driven by rubber bands and actually rose into the air and flew for a short distance. He later built models with two and three planes, placed one behind the other, and also placed one above the other. In 1879 he took out patents on his machine in many countries. On account of the lack of proper motive power he did not attempt to build a large machine until 1901, when he completed a large machine weighing 1870 lb., with a total surface of 1011 sq. ft. He was destined to disappointment because the engine he used, which had been represented as 30 hp., did not develop the power, and the machine was wrecked.

Among those particularly worthy of mention in connection with the engineering development of airplanes are Wenham, who built the first monoplane glider in 1866; Stringfellow, who built a steam-driven model airplane in 1868; Tatin, who in 1879 built a compressed-air driven model, and Hargrave, who built a box kite which was noted for its remarkable stability.

In 1893 the first wind-tunnel experiments were commenced by Philips, to whom we are indebted for much of the data which was useful in the years following his time. And even now his data on wing curves are valuable, and the well-known Philips' entry, used on many curves today, is one of the evidences of his successful effort.

In finally placing the date of the actual starting of the investigation which ultimately rendered human flight possible, we must turn to the years 1888 and 1889 when the following men, though in different parts of the world, set themselves simultaneously to find the practical solution of mechanical flight. These men who are credited with this worthy task were; Professor Langley in America, Maxim in England, Lillienthal in Germany, and Hargrave in New South Wales. The more recent progress of the Wright brothers, Curtiss and others is of course to be noted. The admirable engineering advancement accomplished by these men is already known to all. Since then progress has been rapid and sometimes radical; many theories have been exploded and many more have been proved correct. The advancement made in engineering in the past is only a prediction of the possibilities of the future.

For the past few years, practically the entire attention of the engineering talent of the world has been concentrated on the designing of airplanes exclusively for military purposes, and it is now necessary that serious thought be given to the design of purely commercial vehicles. The development of military airplanes has given us a great amount of extremely valuable engineering data, but not all the efforts of the past to obtain enormous speed and climb at whatever sacrifice of initial cost and cost per mile are of great avail for commercial needs.

The commercial airplane of the future will be used for sport and the carrying of mail, passengers and express. All of these things are now being accomplished successfully but in a limited manner, and to what extent the field of usefulness will be increased depends largely upon the ability of engineers to develop machines better suited to this purpose than those that at present exist.

Factors To Be Considered

Of paramount importance are the questions of safety, low initial cost, low cost of upkeep and low cost per ton-

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mile. A great deal of attention has been given to devices to increase the stability of the airplane with an idea that this will greatly increase its safety. I do not believe that the development of such devices will greatly enhance the future of the airplane. The ease with which pilots have learned to fly existing training machines would certainly indicate that the stability of these airplanes is sufficient for present needs, and investigation will show that the majority of accidents have been due to either collisions in the air or bad landings, and not through any inability of the pilot to control the actions of the machine. The stability of these machines can be increased to almost any extent desired at very little sacrifice of efficiency. In fact, it is perfectly feasible for any aeronautical engineer to design a machine of any type with the surfaces proportioned and arranged so that the machine will be self-righting under all conditions; will not tail spin unless forced into it, and will come out of a tail spin of its own accord. By fixing the rudder on such a machine, it will fly almost indefinitely with all controls released and in case of engine failure will assume a natural gliding angle and maintain that gliding angle until it reaches the ground. With good air conditions, it would even make a safe landing of the ground were suitable. I might add that there are absolutely no mysteries connected with the design of a machine to accomplish these results, and while riding as a passenger in such a machine two years ago, I personally saw all of these things demonstrated in flight.

To my mind, the most important development for the future will be that which will enable airplanes to land in extremely small fields, or literally in a man's back yard, and this must be obtained at not too great a socrifice of high speed. At the present time the load carried on an airplane which has sufficient reserve power for safe flying is about 20 lb. per hp., and a speed range of from 45 to 90 miles per hr. is now obtainable with this loading. It would, therefore, seem that the future airplane should be able to maintain a high speed of 90 miles per hr., speed being one of the main advantages of the airplane over other means of travel.

Among the possible means for reducing landing speed without sacrificing the high speed is the development of more efficient airfoils, devices for increasing the camber of the airfoil in landing, increasing the surface of the main planes, and possibly the development of an angular propeller thrust or auxiliary propeller to reduce the load per square foot of surface. Landing gears having greater shock-absorbing qualities to allow of stalling into a field from a greater height than is now possible would also help greatly. Airfoils having a high lift at high angles with low resistance at low angles, and which still maintain a good lift-drift ratio at normal angles, greatly reduce landing speeds and usually allow of maximum climb at low speeds. It is very probable that the efficiency of the airfoil will be increased to such an extent that any increase of camber would be of little benefit.

With relation to the use of angular propeller thrust or auxiliary propellers, it should be noted that with machines carrying 20 lb. per hp. not more than 50 per cent of the power is necessary for sustained flying at very nearly the airplane's lowest speed. It certainly would be highly advantageous if the 50 per cent excess horsepower available at this point could be utilized as a vertical component to reduce the loading per square foot and thus reduce the landing speed.

It is necessary not only to reduce the landing speed but also to reduce the length of run of the machine after touching the ground which has, in the past, been more or less successfully accomplished by the use of brakes on the main landing wheels with auxiliary wheels well ahead of the center of gravity to prevent the machine turning over. At the same time that we consider the advantage of low landing speeds to get into small fields, we should not forget that it is also necessary to leave these fields. It would, therefore, be highly advantageous to develop machines which will gain their normal flying speed with a short run and have a high climb at low speeds of advance. In getting out of small fields, climb per distance and not climb per time, is the important factor. As previously stated, the development of improved airfoils will better this condition as well as that of low landing speed. Once we have secured this much-desired ability to get in and out of small fields, the safety and usefulness of the airplane from a commercial standpoint will be increased enormously. Not only will we be able to reach points that are not now available near cities, but we can fly over congested or mountainous districts with perfect safety.

Of next importance to safety is cost. There is no doubt in my mind that the future airplane can be greatly simplified and thus greatly reduced in initial cost, and at the same time, be made sufficiently durable so that the cost of upkeep will be a little more than that of an automobile. Most airplanes at the present time, whether they are manufactured in small or large quantities, are practically a hand-made product and this must be eliminated in the future. The concentration of efforts toward enormous climbs and speeds for military purposes has resulted in extremely complex structure, delicate workmanship and expensive materials. However, the military airplane has developed many new materials which will, in the future, result in no only more efficient machines but great reduction of initial cost. The use of waterproof veneer is of utmost importance and if judiciously employed will do away with fully 50 per cent of the number of small and intricate parts. In the past, little attention has been given to the interchangeability of parts, it having been the custom to design each part for the particular purpose for which it was desired without regard to its use for different purposes. Proper attention given to this matter would go far toward eliminating the manufacture of airplanes by hand and would reduce both the initial cost and the cost of upkeep.

One of the airplanes now doing very successful work, which has a range of 540 miles at 90 miles per hr. carrying a load in addition to pilot and passenger of 2000 lb., costs 20c. per ton-mile for fuel. Reducing this range to 270 miles and utilizing the reduction of the necessary fuel for the carrying of additional load, brings the cost of fuel to 13c. per ton-mile. It will, therefore, be seen that proximity of landing fields has much to do with the reduction in cost of the operation of an airplane.

Size and Type of Commercial Planes

As to the size of the future commercial airplane, it is my opinion that the machines most used will be those carrying from one to twelve passengers or corresponding loads of mail or express. But for certain purposes we may expect to see airplanes of a size far beyond our present dreams. However, machines beyond a capacity of twelve passengers become somewhat unwieldy and expensive of operation. Much has been written about the limit of the size of an airplane with relation to the so-called square-cube law, maintaining that increasing the linear dimensions of an airplane increases the surface by

the square, whereas the weight increases by the cube. However, I believe it has been conclusively proved that this law does not hold true, and that it is perfectly feasible by unit structure and the added opportunities for reduction of head resistance, and improved structure, to increase the size of an airplane to practically any extent and with the weight increased little if any more than in proportion to its size. However, in this respect, we cannot hope to compete with the dirigible in which the increase of size becomes highly advantageous, and the percentage of structural weight decreases and the percentage of useful load increases with the increase of size. Due to the limitations of available landing fields, it is probable that the tendency toward increase in size of the airplane will be greater on the water than on the land.

Durability has been of very little importance, but for commercial purposes the upkeep becomes an enormous item of cost. This is true not only of the airplane itself but also of the engine propelling it. Both the initial cost and the cost of upkeep are about equally divided between the engine and the airplane and this engine cost must be greatly reduced. In the most efficient weight-carrying airplanes of today with a loading of 20 lb. per hp. the structural weight of the airplane itself is about 30 per cent of the weight of the machine fully loaded and the weight of the engine is about 20 per cent of the total weight, leaving 50 per cent for fuel and useful load. For a range of 600 miles, the weight of the fuel is about 20 per cent, leaving about 30 per cent for useful load. Improvements in the airplane structure will greatly reduce the percentage of structural weight and will allow the use of heavier engines with corresponding reduction of cost. However, it is very doubtful if the trend of engine design will be in this direction, as efforts will be concentrated toward the increase of the percentage of useful load carried.

I have previously stated that we must not sacrifice high speed for low landing speeds and likewise we must not sacrifice this high speed for reduction of engine cost. It would seem to me that one of the greatest advancements that could be made in engine design would be the development of an engine which would maintain its horsepower at high altitudes. If the horsepower could be maintained at high altitudes, the speed of the airplane would be greatly increased thereby, and it would then be permissible not only to decrease the landing speed without sacrificing the high speed but the use of engines of lower horsepower would be possible. It is probable that the development of an engine of this type would demand a variable pitch propeller to get the maximum speed at altitude. If such a propeller were used, it would not only increase the speed at altitude, but by reducing the pitch and allowing a corresponding increase in engine speed, the efficiency of the propeller would be increased at low speeds of advance so that the landing speed of the airplane would be greatly reduced.

As to the particular type of airplane to be used for commercial purposes, the tractor would seem to be most advantageous. Inasmuch as safety is of the greatest importance and most wrecks occur in landing, the pilot and passenger should be located well to the rear of center of gravity, so that the heavier parts of the machine, such as engines, etc., may reach the ground first, as they are much more capable of absorbing the shock than is a human being. The two classes of accidents which are most common to the airplane are wrecks due to bad landings and nose dives resulting from engine stoppage in climbing out of a field when the altitude is not sufficient for the machine to recover.

It would also appear that multi-engined machines will not only add to the safety of the machine but also reduce the cost per ton-mile and by decreasing the liability of breakage thus reduce the cost of upkeep. You will probably assume that the use of multi-engines means an increase in the weight of the powerplant, but on investigation it will be found that the opportunities given for the reduction of the structural weight due to the distribution of loads are so great that the structural weight of the machine will be decreased in far greater proportion than the weight of the engines is increased.

For long flights the weight of fuel is a very large proportion of the total weight of the machine, and as the journey progresses the fuel is reduced and the range may be greatly increased by throttling the engine. You are all aware of the fact that throttling an engine is a most inefficient manner of reducing horsepower and with the multi-engined machine it becomes perfectly feasible to cut out one or more engines as the case may be when the flight is partially completed, leaving the remaining ones operating at maximum efficiency and best economy.

A multi-engined machine is undoubtedly much safer, as we can assume that all of the engines will very seldom stop at once, and even though the remaining engine or engines are not sufficient to maintain constant altitude, the gliding angle will be enormously increased. For small passenger carrying machines the twin engines are extremely advantageous as it is then possible to design a tractor type of airplane which will be perfectly clean and avoid the objectionable oil which always drifts back into the pilot's face in a single-engined tractor type. Maneuvering on the ground also becomes much easier and by throttling one engine or the other the machine can be maneuvered with the wind without a group of mechanics to assist the pilot.

I would like to point out at this time that the greatest assistance which can be given the airplane engineer in the design of commercial airplanes is the development of suitable engines of which there are very few in existence at the present time. As with the airplane itself, all attention for the past few years has been given to engines of very high horsepower and extremely light weight, with initial cost and cost of upkeep as purely secondary considerations. It is probable that some of the existing airplane engines, if built in enormous quantities, could be produced at a reasonable cost, but the production of commercial airplanes is, at the present time, somewhat limited and the growth of the industry must necessarily be gradual. It would, therefore, seem that the production of existing type of engines will not be sufficiently great to get the cost down to a reasonable basis. Engines of medium horsepower would be highly advantageous for smaller types of commercial planes, and a very satisfactory sportsman's machine of the twin-engined type with units of 60 or 70 hp. would be a desirable product, and it should be possible to produce such engines at a comparatively low cost. For this type of machine the air-cooled type of engine would be particularly desirable inasmuch as the engine can be of comparatively small size and small bore and can be exposed in a manner which would not be practicable in a single-engined type. All air-cooled engines which have previously been brought out have been of a type in which efforts have been made to reduce the weight to an extent far beyond that of the water-cooled type. I believe that an air-cooled engine of medium horsepower, weighing the equivalent of a fully equipped water-cooled engine including radiator and water, would make an efficient powerplant and one which could be produced at very low cost.

The Principles of the Wheeled Farm Tractor

THIS paper, by Edward R. Hewitt, which was presented at the Annual Meeting in New York City and at the Tractor Meeting in Kansas City, was productive of a large amount of discussion. The remarks of the various speakers at the two meetings and written discussions submitted by others are presented herewith. The paper was printed in the February issue of THE JOURNAL.

THE DISCUSSION

E. R. GREER:—In pointing out the effect of lugs or cleats on traction wheels, Mr. Hewitt has overlooked the advantage that can be obtained from spiral extension cleats when they are properly spaced. This type of cleat not only cleans itself, but it compresses the soil without shearing it, and, due to the slight slipping of the wheels, there is a side-thrust on the ground not actually rolled over by the wheels. I do not think that the shearing strength of the soil times the width of the traction wheel rim, is the limit of possible tractive effort from cleats. Before condemning tractors with front-wheel drive, it might be well to consider that about 80 per cent of the work done by tractors is on more or less hilly ground, where this type of drive has a tremendous advantage. As the weight on the rear or steering wheels becomes greater when going up hill, the control of the tractor is made more positive, so that this difficult condition is easily met. This type has another great advantage in that it greatly reduces the drift of the implement when used on side hills; it also makes it possible to build the tractor so that over 85 per cent of its weight is normally on its drive wheels. It can never rear up and kill the operator. The percentage of load for a tractor engine is usually nearer 90 per cent than 50. In deciding on the proper size of tractor it is hardly right to consider plowing only. It makes a great difference whether the tractor is to be used on a "small grain" farm or where corn is the principal crop. Plowing in any case is less than 50 per cent of the work to be done.

DANIEL ROESCH:—Referring to the chart showing the relationship between fuel consumption per brake horsepower per hour, per cent of full load at 1000 r.p.m., and the suction on intake manifold in inches of mercury, the curve of the best result probable from the Otto cycle intercepts the fuel consumption ordinate at 2.3 lb. of gas per b.hp. per hr., with the engine at zero load. This is a condition that can never be realized in an engine having friction, since the figure is obtained by dividing the pounds of gasoline necessary to operate the engine by the load in brake horsepower. The quotient is infinity and the curve should show asymptotic to the ordinate with somewhat the same characteristics as the other curves at light loads. The relationship between the upper horizontal scale of intake manifold depression, and the lower horizontal scale of per cent of full load is worthy of further inspection than that given by the author. It is to be noted that the upper scale is not proportional. Plotting these two variables on coordinate paper shows results consistent both in themselves and as compared with numerous parallel tests conducted in the laboratories of Armour Institute of Technology. The effect of the particular compression used in an engine will, however, greatly modify the upper scale. This upper scale as shown indicates a 1-in. carbureter resistance at wide open throttle while operating at 1000 r.p.m. and by exterpolation, 18-in. manifold depression when the engine is operating at 1000 r.p.m. without external load. Factors of increased compression, maximum, and decreased frictional losses, mechanical and fluid, may increase this latter figure to 20 in. of mercury depression or more. These same factors may decrease the right-hand scale limit of intake manifold depression from 1 in. of mercury to 0.5 in. less. Tests made on the same engine at 1000 and 2000 r.p.m. from wide open throttle to no load show practically no variation in the relationship between intake manifold suction and per cent of full load. In connection with the author's discussion of the curves shown on this chart, it would appear to have been desirable to note the feature of inherent lower compression occurring with increasing manifold depressions, and producing the high fuel consumption at the lighter loads. Along these lines he discusses the relative frictional losses in a tractor and an automobile, but omits bringing out the relative loads on the engine and power transmitting parts of the two machines. Observations by the writer, extending over a period of several years, show from 13 to 16 in. of manifold depression in an engine driving a passenger car at say 20 miles per hr. Taking the chart in this paper, we find this to correspond to from 22.5 to 12.5 per cent of full load. The car frictional loss in per cent will be higher under these conditions than when the case of the tractor is taken and its engine operating at 60 per cent or more of full load, at the particular operating speed. The frictional losses, actual or in per cent, must be taken under parallel or all load conditions for comparison.

The method of estimating the approximate horsepower of the engine in a tractor by observation of known intake manifold depressions obtained from tests, appears commendable where extreme accuracy is not desired. There is an opportunity, however, for introducing large errors when dealing with differences of power determined under variations of mixture, spark advance, cooling water, barometric pressure and air temperature and humidity.

The further reference of the author to intake manifold suctions are certainly worthy of extended study, and undoubtedly will serve to depict operating and test conditions more clearly and correlate them.

H. L. HORNING:—Our experience indicates that tractor engines should be so designed as to have maximum torque, about 30 per cent below governed speed, and a governed speed slightly above the speed of maximum economy. Tractor engines in our experience do not work at half load, but at such a load as to be beyond the limit of the governor; hence the advantage of a rising torque curve at speeds decreasing from governed speed. The average speed of tractors is governed not by the governor or design, but by the maximum speed at which the farmer cares to ride, which is almost always determined by the depth of the plows. Hence the engine is working at overload most of the time, as the average shop man would say. A distinction which tractor men should learn with regard to engines before they can get very far is, that an overload on a tractor engine must not mean a load which in-

jures the engine through continuous performance. There is no load which can possibly injure any first-class tractor engine. The term overload as used can mean only one thing; namely, that the horsepower at the drawbar is not sufficient to maintain drawbar demands and governed speed. The thing to suffer must be the speed. It does little harm for the speed to drop. The torque, hence drawbar, must persist and so must the engine. Speed of the tractor is the only factor which can vary without serious consequences at the maximum demands of the tractor. As it actually happens, the farmer drops the plow as deeply as possible until the engine slows down to such a point that he simply cannot tolerate the speed. If the engine slows down below its speed of maximum torque before the farmer gets restive, the engine dies. The farmer usually becomes impatient and lifts the plow, and the engine speeds up to a rate which balances with the torque demand of lesser plow depth. And so the law of supply and demand works out through the plowing season with the same flexibility as it does in the broader economic fields. The farmer demands all he dares from the engine. The engine gives all it can. If the farmer demands too much, the engine supplies less, which is the equivalent of the price of a commodity going up. If the farmer eases off on the demand, the engine gives more, which means that price for the commodity, traction, decreases. Those who have developed a governor through years of experience know that its wear is very moderate in plowing work, but it wears out rapidly in belt work, a strong proof of the statement of average use in which the governor is wide open and the engine operating by itself in the zone of stability.

The price of fuel must be out of all proportion to current commodity prices to make fuel economy of primary and absorbing interest to farmers. Our experience is that farmers buy kerosene tractors but burn gasoline. The kerosene attachments up to this time are mostly safeguards against exorbitant prices of gasoline.

Generally speaking, tractors must give larger returns than they have in the past. This particularly applies to small tractors of the two-plow type, which operate under handicaps in competition with larger sizes.

There is little to be pessimistic over, as we have not yet manufactured 7 per cent of the tractors necessary to saturate the market, and our experience is necessarily slight and our ignorance profound.

R. B. SHOOP:—The shape of the cleats has a definite bearing on the effectiveness of the field resistance. If a cleat or lug disturbs the surface of the soil when entering the ground, the effective face of the resisting surface has been reduced, with a loss of footage, especially if the soil is light and the cohesiveness of the ground is almost reached. My observation has been that the movement of the soil under the backward pressure is almost the form of a right-angle triangle with the hypotenuse as the line of breaking soil. If the cleat has an involute curve the ingoing and outcoming movements are vertical and do not break up the soil, but rather compress it, giving more resistance to the action of the lug.

There have been pro and con arguments relative to the size of the tractor. Some years ago the president of one of the largest tractor companies started considerable discussion when he pronounced the small tractor an economic impossibility. He neglected to take into consideration the tendency of the modern farms to use power, when possible, and would not consider that the large tractor did not yield suitable returns, on the small farm, either as an individual or community purchase. The greatly increased production of 1918 was due in no small way to the two, three and four-plow tractor; in fact, without the small one-man machine, operated by the boy or elderly man, it would have been impossible.

I have observed that it is seldom necessary to put any devices on a tractor to induce the farmer to work his machine at nearly maximum capacity; on the contrary, tractor engineers have been trying to find some way to prevent the abuse of overloading. The average farmer, if he considers that his tractor can do more work, will unhesitatingly put more implements in service. A tractor in the hands of a farmer works at approximately 90 per cent of its capacity from 70 to 80 per cent of the time.

A three or four-speed transmission would sometimes be of advantage, but when the extra mechanism and extra weight, together with extra cost, are considered, it is of doubtful economic value, especially when 1 lb. extra weight means 1 gal. of fuel in the life of the machine.

A. F. MOYER:—I undertook research on the performance of wheels in soft soil about 2½ yr. ago, but have been able to experiment only on rolling resistance, although the intention of experimenting on tractive properties of drive wheels was kept continually in mind. This work is just about to be renewed on a large scale after interruption by special war training of the U. S. Army and Navy in our laboratory. If Mr. Hewitt wishes further "precise data on this subject," the original record books will be gladly opened to him at any time he wishes to call at the Experimental Engineering Laboratory, University of Minnesota. His statements regarding the friction of drive wheels on the ground is of much interest, but may not be fully accepted by all. It would seem that the adhesion obtained by a series of narrow spade or cone shaped lugs might be different from that resulting from long cleats extending entirely across the tire.

The power required to propel the tractor as determined by the author is based on interesting data which will permit the bearing values of different soils to be numerically determined from formulas. The author does not state whether the water cart used in his experiments was of two or four wheel construction, and, if of the latter, whether the rear wheels tracked the front ones. The rear wheels of a tractor are usually of a broader tire than the front pair, and do not always run in the same track. The statement of the variation of resistance with different wheel diameters would be in general correct if it were amended to read, "varies inversely *with* the diameter" and not "*as* the diameter." Such a mathematical relation is only vaguely approximate. The amended clause signifies that as the diameter increases resistance decreases, but the relation involves at least the square of the diameter based on theoretical grounds, and experiment has shown that a still higher exponent ought to be used, as the soil will bear up more per cubic inch displaced under a wheel of large diameter than under one of small diameter. The author states that he notes no marked difference in the resistance to rolling between 1 and 3 miles per hr. I have repeatedly obtained differences of 15 per cent and often more between these limits, resistance increasing with velocity.

The author's method of measuring the power input in his tractor is of considrable interest and at least approximate. Without research on the method, the possible error cannot be prognosticated. This is one of the many instances in which approximate data are better than none.

The discussion of torque load on the engine with relation to fuel economy is true when the engine is turning

at its best speed, but shifting to a higher gear when the drawbar load becomes light will usually be accompanied either by a speed too high for the implement, or an engine speed below that of the governor, which is impractical, and probably with inferior fuel economy.

To one who knows the history of the large gas tractor as pioneered in Minneapolis 10 yr. ago, the consideration of tractor size will exclude the very large unit. Without question the two-plow unit is too small for economy. From three to six plow sizes, in my judgment, have the best possibilities, with a slight preference for the four-plow machine.

R. W. LOHMAN:—It is indeed refreshing to have a manufacturer of tractors come right out in the open and say that if, for instance, a maximum theoretical capacity of 100 acres per day is provided in tractor equipment we may possibly find at the end of a week that the average acreage handled has been as much as 50 acres per day. If other tractor makers had been equally frank, or as well informed, in the past, power farming might be more favorably regarded by the average farmer than it is today. The usual method of considering the expense of any farming operation, say plowing for example, as the simple cost of the crew, fuel and supplies, divided by the maximum number of acres which a tractor can plow *while actually in motion,* is wholly erroneous and misleading, omitting, as it does, all indirect production labor, all indirect supplies and material and all fixed charges. As the result of 8 yr. detailed observation and experience with various tractors, 50 to 60 per cent of the actual available plowing hours is all that the average farmer, with ordinary mechanical ability, can be expected to get out of his equipment.

In determining the capacity of certain equipment required for the cultivation of 24,000 acres this coming year, we found, for example, that a 120-hp. tractor should, theoretically, plow 62.5 acres every 10 hr., or 125 acres per night and day shift of 20 hr. Falling back upon our records, however, we found that only 80 per cent of this, or 100 acres, was the best performance we had been able to maintain, and this only by extremely careful supervision, ample stock of repair parts, proper shop equipment, provision for rapidly loading with oil, gas, water and grease twice a day when plowshares were changed, taking hot meals out to the crew in midshift, and always taking them to and from the equipment in automobiles on regular schedule time. But still another factor enters, and, while it may not be concerned with the engineering design of the tractor, it is of great importance to the operator. It is the good weather factor. We found that, on the tract in question, the days upon which it did not rain were only 75 per cent of the total elapsed days in the plowing season. This still further reduced the available time, or the *effective* plowing capacity per tractor, by another 25 per cent, or to 75 acres *per day and night of elapsed time.* Thus the total reduction factor, from the 125 acres per 20-hr. day, which it is theoretically possible to plow with such a tractor to the 75 actual acres which can be plowed throughout any given month of the plowing season, is 60 per cent, and equipment was purchased on this basis.

The author states that if the weight per inch of width on the drivers of a round wheeler exceeds 200 lb. per in. of width, the tractor becomes *very* inefficient; that the power consumed in rolling friction becomes a large percentage of the total developed; that in his own tractor, by throwing all the weight on the rear wheels by applying full engine torque the rolling friction is *increased* 25 per cent, and that even in a properly designed tractor the normal rolling friction on fairly soft or plowed ground will be up to 25 per cent of the total power delivered to the rim of the wheels. As a matter of fact, many of the best known and widely sold round wheelers have weights per inch of width of from 250 lb. with wheel extension rims, to 480 lb. without rim extensions, so that in general the rolling friction may be expected to exceed *greatly* the figures just given. The author then proceeds to say that if it were not for the complication and high maintenance cost of the tracklayer or caterpillar type, such a machine *might* be of *some* use, *somewhere,* say on soft ground, for instance. At this point it may be properly asked, how many times in the career of a farm tractor is it operated over such ideal surfaces as those described in the author's paper as hard macadam, dry short clover or sod? Just once, while the farmer is breaking up his new prairie sod or old grazing land. For the rest of its life on that farm it is operating over land which has already been plowed, harrowed and disked, or on corn or wheat stubble or potato fields, which are just about as soft and powdery as good farming methods can make them. In other words, why discuss the performance of a round wheeler on hard ground when 99 per cent of its work must be, and is, done on soft ground with an admitted power loss, in addition to all other mechanical losses, right at the rim of the wheel of from 25 to 100 per cent of its full rated output? Many and many a time I have operated 60-hp. round wheelers over plowed ground in hard clods, with a load of 50 ft. of heavy spike-toothed harrows, and upon coming to a part of the field where there was a genuine mulch, thereby imposing a much lighter load on the harrows, but also removing all semblance of adhesion between the rim of the drivers and mother earth, found further progress impossible; the drivers simply slipping and digging holes in which they would soon bury themselves if the power were not shut off. The author states that the over-all efficiency, or the ratio of the engine horsepower to the drawbar horsepower, has never been less than 65 per cent in cases under his observation. The above case of harrowing is simply cited as one instance out of a dozen situations occurring daily in farming operations of any magnitude, in which the over-all efficiency is absolutely zero.

Now what are the losses in, and what will a tracklayer do on loose farm soil? The only definite comparison available at this moment is a test made by hauling a 75-hp. caterpillar, weighing 26,000 lb., at a speed of 2¼ miles per hr. on hard packed snow. The drawbar pull required was 1800 lb. This is equivalent to approximately 11 hp., or 14.7 per cent of the rated horsepower of the tractor, or an *over-all* efficiency of 85 per cent, against the 65 per cent above referred to. Of course, there is an error here to the extent of the additional losses occurring in the transmission members when they are under full engine load, instead of running idle. The value of this additional loss has not been determined. A caterpillar running over a plowed field will leave as the only indication of its passage a series of splashes of powdered earth, representing former clods lying on the top of the ground, and which, having too large an area to be depressed quickly to the general surface level, are crushed. There is positively no rolling down of the ground in a pair of tracks from 2 to 6 in. deep, or more, as is always the case with the wheel type.

The author states that on sandy ground the maximum coefficient of adhesion will be about 30 per cent. The detailed specifications of "sandy ground" are not given,

but since in sand the adhesion of a round wheeler is from nothing to 5 per cent, this maximum is open to discussion, as is also 43 per cent for damp sandy ground. On a test made with a caterpillar weighing 7000 lb. and having a ground pressure of 5 1/3 lb. per sq. in., less than that under a horse's hoof, the tracks were locked by a brake and the tractor was then towed by another machine. The average coefficient of adhesion was found to be about 670 lb. per sq. ft. of track surface, or 87.2 per cent of the weight of the tractor. This varied from 50 to 100 per cent, the lowest being on wet, slippery clay roads and the highest on good, hard sod. Dynamometer tests with a 120-hp. tractor weighing 28,000 lb. indicated a sustained drawbar pull of 15,000 lb., or a coefficient of adhesion of 55½ per cent, on a field covered with hard packed snow.

The author states that few machines in this country are proportioned in such a way that the full engine power can be applied on low gear without taking the front of the tractor off the ground, which interferes with steering, is dangerous and prevents full utilization of the available power. In this connection the following test of a caterpillar may be of interest. A gun mount weighing 55,000 lb. was hauled up a grade of 43 deg., the drawbar pull and the weight of the tractor indicating a coefficient of adhesion of 93¼ per cent, the surface being dry clay loam. This considers the angle of inclination to the horizontal, for on this hill the track pressure normal to the ground was only 8.05 lb. per sq. in., against 11 lb. per sq. in. with the tractor on the level. In regard to lifting the front wheel of a tractor off the ground, thus making it impossible to steer, many track-layers are now built without any front wheels at all, steering being effected by clutches on each track drive sprocket, and even if they have a front wheel they can be steered while the wheel is in the air by these clutches.

Thus it would seem that the track layer or caterpillar type is not only superior to the round wheeler in every one of the features discussed, viz., coefficient of adhesion, over-all efficiency, and greater ratio of engine horsepower to available drawbar pull, but that it will actually deliver drawbar pull on soft ground, which, after all, is really the only ground with which the farmer is concerned in practice, and in which the round wheeler, unless habitually and woefully underloaded, will actually stall, and have to be dug out.

A MEMBER:—What experiments are you conducting in regard to a big caterpillar design paddle-wheel tractor?

MR. HEWITT:—I have conducted very extensive experiments on the design of lugs and grouters of various kinds, and I find that the amount of pull which will be added by any devices of this kind depends on the shearing coefficient of the soil below the edge of the grouter. Some soils have a high coefficient and others a lower one. In sand you will get practically no added pull. There are cases where the very shallow grouters are more efficient than the deep ones, because if you do not cut off the root at the bottom of the sod, and your grouter goes into the sod, it will pull more than if it simply goes down below it. The clearing of the lugs was very interesting, because I found that a lug set at an angle of about 30 deg. and inclined upward about the same angle would practically clear itself under all conditions. The reason for that is that there is a slight sliding action due to the pull on the lug, and the grouter being inclined this way enters the ground flat, and as it leaves its position is almost vertical. I also found that it was possible to put a steel rim around the wheel 1 in. higher than the top of the lugs and run on that steel rim on the macadam road and not damage the road at all. That added very much to the operation of the machine. We can run on the road at any time, and the lugs do not touch by 1 in.

F. C. GOLDSMITH:—Have you ever conducted any experiments to determine the percentage of loss? In a paddle-wheel type you would expect a larger loss.

MR. HEWITT:—I think there is a larger loss, especially in sticky soil and wet soil.

B. S. PFEIFFER:—Did you find any difficulty in your tests when you ran on the top curve, with the caterpillar type tractor?

MR. HEWITT:—No, it is practically the same thing in the caterpillar, and a wheel twice as large in diameter will give you about twice as good results as one about half the size. The caterpillar being flat, gives you a much larger surface, but with a 6-ft. wheel we get about 20 in. in contact multiplied by the width.

MR. PFEIFFER:—Would not that pressure remain about the same—would it not be a flatter curve?

MR. HEWITT:—It might be. The caterpillar I used had only a narrow track about 6½ in. wide, and the weight per inch was pretty high on it. It was not a very good design of machine.

DENT PARRETT:—From the practical standpoint, in the first place, there is a very small percentage of work done on ground within 24 hr. after it is plowed; either the ground is harrowed at the time it is plowed or else the disking or harrowing operation takes place long enough after the plowing so that in most cases a crust is formed on the ground and the weight-carrying capacity of a wheel is not in direct proportion to its width. In other words, it takes a certain effort to break down the crust. Therefore, a narrower wheel will carry a higher proportion of load per inch of weight than a wide one. Another factor which comes in is that it takes a certain amount of pressure to push each lug into the ground, and a tractor wheel equipped with grouters would have a greater weight-carrying capacity than a plain wheel would. In cases where the operator is a hired man the results may be very poor, but in the Middle Western States where the farmers are very enterprising, and many of them run their own tractors, or else they are operated by the sons of the owners, they will get out and work very hard for a few days to accomplish their task. The report of one operation which extends over a period of time, was the plowing in Texas. I had a report from there which showed that a three-bottom outfit plowed 280 acres of land in 40 days. They were not in the field over 10 hr. in the day and in that time the tractor was oiled and cared for, there were practically no repairs, and for the 40 days it averaged 7 acres per day. This may be a little higher than average results, but it shows what can be done on a farm where the tractor is properly operated in an aggressive way.

MAJOR L. W. CHASE:—I have found in the Central West that farmers do not care so much about the cost as they do the opportunity to get their work done quickly and at the proper time. One big farmer, who, due to the use of tractors in Nebraska, has been able to reduce the number of his horses from sixty to eighteen, made the statement a year ago last spring that by plowing at the proper time with tractors he felt he could get 5 bu. more wheat per acre than he would if he let his plowing drag along through the season, and because of that he has purchased a third large tractor. Plowing is not all of the farm operation today; it is one around which we talk because it is one point that we can get down to figures on, but there are many operations that the tractor will do, and do more quickly and often more cheaply than horses. One illustration is that farmers can haul manure with an

ordinary three or four bottom tractor as cheaply as they can haul it with horses. This was before war conditions. During the war the tractor has entirely superseded the horse as to cost of many operations. The fuel consumption figures as given by the British Royal Agricultural Society in its operations are noted the several hundred tests that have been conducted in this country, the largest that I have any record of, where conditions were only slightly worse than usual, was about 4 gal. per acre, and the best records obtained in plowing about 5 or 6 in. deep, were a trifle less than 1½ gal. of kerosene per acre. It is ordinarily expected that a tractor should run on about 2 gal. of kerosene per acre. But fuel consumption is not the deciding factor. It is believed that the farmer wants a tractor which will do all kinds of operations and one that will do them at least 100 days per yr. and for several years, even at the cost of more fuel. Now one thing that has been brought out is the matter of speed. As I sat here I figured up that with a three-bottom outfit, starting in the spring, plowing for oats under normal conditions, it only takes about 4½ hp., but before that farmer gets his wheat put in in the fall and puts it in under the average farming conditions, the same engine going at the same speed requires over 19 hp. So you can see that the matter of gears enters materially into the design of a tractor. The foregoing assumes a 10 per cent grade. In our country a 10 per cent grade is a pretty good one. I notice here in the East that it is not very heavy. In these tests of wheels, I understand a trailer was used. What would be the effect as to rolling friction if that was a tractor wheel? What is the relation between the trailer wheel and the tractor wheel?

MR. HEWITT:—I think the tractor wheel would act exactly as the trailer wheel.

MAJOR CASE:—I have understood that the tractor wheel is different from the trailer wheel in that the tractor wheel only comes in contact with the surface of the ground on the front half of the wheel, while the trailer wheel has a certain percentage of contact behind the line that passes vertically through the center of the wheel. This was the result of some investigation that Professor Seaton started to conduct at one time, and I have by observation in the various tractor tests noted the same condition. It was because of this that I felt there would be a difference in the rolling resistance between a tractor and a trailer wheel. Another point touched upon in the paper is the matter of the length of lugs or grouters, and Mr. Hewitt even speaks of the smooth wheel. A smooth wheel might do fairly well under ideal conditions, but you all know that when you take your automobile out and start to church on Sunday, it takes only about 2 rods in a mud hole to put the car out of commission. Now it is the same thing with the tractor; it only takes about 10 ft. of hard surface, with a little slippery mud on top of it to cause the wheels to slip, and for that reason I feel that his paper is a trifle misleading, because you cannot under any circumstances, on farms, get along without grouters of some kind. Mr. Hewitt spoke about the load per inch of weight being a direct function of the drawbar pull of the wheel. Does not the diameter of the wheel also introduce a function there which is not stated?

MR. HEWITT:—It works directly as the diameter.

MR. GOLDSMITH:—I regret very much that the kind of soil upon which the tests of the friction of the wheel on the ground were made is not stated. It seems to me, from what I have seen at the show, that most manufacturers have very long cleats. If the conclusions drawn by the author are true, the shear is entirely at the bottom of the cleat and a ½-in. cleat would be as good as a 3 or 6-in. one.

E. A. JOHNSTON:—The experience of tractor manufacturers is that if you supply tractors to many different portions of the world you will be compelled to supply many different forms of cleats and many different widths of tires. The number of pounds per inch of tire varies greatly with the conditions under which the tractor operates. The variety of cleats will also vary considerably. There are a great many things to consider; the road laws of different countries and the conditions under which tractors operate vary so greatly that a very large number of lugs and tire widths is required to take care of all these different requirements.

RURAL MOTOR EXPRESS

THE rural motor express is another fundamental step in progress. It is as important in its way as was the coming of steamboat transportation, which is so aptly described by Dr. Max Farrand. Robert Fulton demonstrated the possibility of successfully using steam in water transportation for commercial purposes, by running the Clermont from New York to Albany. Not long afterward, in 1811, the building of a steamboat on the Ohio River opened a new chapter in the history of the West; the era of upstream navigation had begun. Without such assistance it does not seem possible that internal commerce could have developed in the United States; and certainly not in the way in which it did. When 2,000,000 or 3,000,000 people were living west of the Alleghany mountains, and offered the markets which Eastern manufacturers were seeking, the demand for improved means of transportation between the sections was inevitable and soon became irresistible. It was only too evident that the Old National Road, opened shortly after the War of 1812 and largely used, could not supply the needs of the time; something more and something better must be had.

THE AMERICAN SOLDIER

ABOUT the finest human specimen atop of earth is the American soldier—rough and ready, grumbling, never giving up; always able to laugh, even at his own plight; a holy terror in a fight; ruthless to an enemy capable of resistance; generous to a fault to a beaten foe; hating nobody, fearing none; with guts enough to storm Hades and the gentleness to win a child.

—George Pattullo.

Pneumatic Tires on Trucks

By B. B. Bachman[1] (*Member*)

Motor Truck Meeting Paper

THE use of pneumatic tires on trucks has been a subject of considerable interest for some years. At the annual meeting of the Society in 1913 I presented a paper on this subject and covered the matter in a more or less general fashion. Since that time considerable progress has been made in truck construction and a very great advance in pneumatic tires due to the appearance of the cord tire, whereas at the earlier date the fabric tire was used almost exclusively. The cord tire, permitting the construction of very large sizes with corresponding carrying capacities, has made it possible to use the pneumatic tire on trucks up to 3-tons capacity and in some cases even beyond.

The most pertinent questions that arise in connection with determining the feasibility of the use of pneumatic tires are probably these:

(1) On what sizes of truck can they be used?
(2) In what class of service?
(3) On what kinds of road?
(4) What advantages are obtained?
(5) What disadvantages become evident?
(6) Will it be necessary to radically modify truck construction to use pneumatic tires most economically?

An analysis of data contained in *Automotive Industries*, Jan. 16, 1919, shows that on trucks ranging from 1000-lb. to 5-tons capacity the maker's equipment for tires is as given in the accompanying table:

Capacity, tons	Number of models	Solid only	Pneumatic only	Optional
½	14	0	13	1
¾	18	3	14	1
1	64	41	8	15
1¼ to 1½	71	59	1	11
2 to 2½	128	118	2	8
3 to 3½	81	80	0	1
5	62	62	0	0

It must, of course, be recognized that this does not give an indication of the cars which have had their equipment changed by the owner after purchase, and probably does not give an indication of the cases where pneumatic equipment has been furnished at the customer's request. Conversely, if a sufficiently large demand had arisen, the manufacturer would undoubtedly have recognized the fact by listing optional equipment.

The Field of the Pneumatic Tire

Viewing the figures with these facts in mind, it would seem to be safe to say that for vehicles up to 1500-lb. capacity pneumatic tires only are proper. From 2000 to 3000 lb. inclusive there is a strongly marked tendency toward pneumatics, and on 2 to 2½ ton trucks they are just making an appearance, while on the larger sizes there is practically no evidence apparent from this source. We have all seen large trucks of 3, 4 and possibly 5 tons capacity with pneumatic equipment, and the fact that makers are not listing them would indicate that the proposition is still in the experimental stage.

On the smaller-sized vehicles in the delivery field, there is hardly room for discussion as to the desirability and even necessity of pneumatic tires, as the speeds are high and construction follows closely on passenger vehicle lines. If these cars were made rugged enough to operate on solid tires, it would only require the increasing of the capacity of the spring equipment to make them suitable for possibly double their present ratings.

In the 2000 to 3000 lb. class, it is my opinion that except for limiting factors which will be covered later, all vehicles would operate more economically and satisfactorily on pneumatic equipment. The reason for this opinion is that on this size of vehicle the tire equipment does not become so expensive in initial installation as in larger sizes, and it is easier to realize on the advantages of increased speed, etc., without attendant difficulties.

Vehicles in the 2 to 2½ ton class are, I believe, likely to follow the last class, but to do so it is my belief that a different theory of design will have to be followed. Generally speaking, the cars in this class are too heavy in proportion to their capacity. This means that to carry the unnecessary burden caused by solid tire construction, excessively large and consequently expensive tire equipments must be used. It is only natural therefore that when the customer is faced with an initial equipment expense of 100 to 200 per cent greater than for solid tires there is considerable hesitation about going into the proposition.

For the 3 to 3½ and 5 ton classes the foregoing remarks apply with possibly greater force. Also the utility of this equipment will probably depend on the future development of long distance truck haulage.

During the conditions existing for the last eighteen months in the congestion of railroads and terminals, etc., the use of large trucks for long distance hauling has come into considerable prominence. Under these extraordinary conditions many considerations which would normally have to be reckoned with were left out due to the absolute necessity of utilizing every available means of transportation.

The increase in operating speed demanded by these conditions to obtain favorable results on these larger sizes has undoubtedly been followed by high mechanical depreciation on the part of the car and rapid disintegration of road surfaces. It is only natural, therefore, that the pneumatic tire was resorted to as a means of alleviating both these conditions, and undoubtedly results obtained were in many cases successful.

The question still remains to be answered, however, as to what the future will show as to the radius in which truck transportation can compete with various other forms and what size of unit will be most satisfactory.

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These questions hardly have a proper place in this discussion and are mentioned only to indicate that they exist and will have a bearing on our present subject.

To sum up then, it seems that for vehicles up to 1500-lb. capacity inclusive pneumatic tires should be used except under very rare conditions. Vehicles of 2000 to 3000 lb. capacity should be rapidly changed to pneumatic equipment in the large majority of cases, due to the appearance of the cord tire. A considerable percentage of 2 to 2½ ton vehicles will probably be placed on pneumatic equipment when the subject has been more clearly demonstrated to the public and after design changes which may be found necessary have been made. On the larger vehicles, it is my personal belief that a great deal of work must be done on a complex subject involving transportation problems, road construction, vehicle construction as to chassis, powerplants and wheels, and also with the tires themselves and rim equipment, before any definite prediction can be made.

The type of service in which pneumatic equipment should be used will cover first of all light delivery service of all kinds, for it is in this field that the small car up to 2000-lb. capacity is used.

In the sizes embracing the 3000 lb. and 2 and 2½ ton classes, the conditions where materials are fragile or where delivery conditions require long runs with frequent stops are the places where the best showing has been made. Typical instances of this kind are delivery of foodstuffs in suburban territories and the recent development of the parcel post system in hauling farm products into the market.

With the larger size trucks the only place, it would seem, for the use of pneumatic tires is in that class of service covering long hauls, where speed requirements are high. One reason for making this statement is that with these larger size vehicles the loss in time due to improper handling facilities at terminals is so great that where hauls are of normal length more can be gained in speeding up the handling than by increasing the car speed.

A limiting factor to all of the preceding statements is to be found in the character of roads on which pneumatic equipment is operated. When vehicles are operated in part or entirely over roads which are littered with scrap metals, glass, etc., as is the case in certain kinds of work, the pneumatic tire will not have a fair opportunity to demonstrate in a satisfactory manner.

The modern cord tire is excellent for operation on almost every kind of road. The structural strength of these tires renders them less susceptible to injury from stone bruises, etc., when operated on rough roads if the proper inflation pressures are used than with the fabric type. The types of treads which have been developed are of great assistance in snow, mud and on wet surfaces. In consequence, with these advantages it is safe to say that the pneumatic tire will compare favorably with the solid under almost every condition of road.

Advantages of Pneumatic Tires

The advantages claimed for the pneumatic tire are numerous. Some of these claims are so obviously correct as to need practically no discussion; others are open to considerable question. Also, as with every matter of this sort, the answer is not to be obtained from any one factor in the problem, but after the bearing which each factor has upon all the others has been given consideration.

The claims of advantage which are made may be listed as follows:

(1) Reduction in mechanical repairs
(2) Increase in permissible speed
(3) Decrease in gasoline consumption
(4) Decrease in oil consumption
(5) Less fatigue for men
(6) Lessened depreciation of roads
(7) Greater tractive ability

The reduction of mechanical troubles can be accepted as a fact almost without comment. One point to be considered, however, is that while the net trouble is reduced, it is apt to change in character. With solid tire equipment, due to the shocks on the portions of the chassis which are not spring borne, the greater amount of difficulty is caused by the wear and looseness developed by this action. The small amount of resiliency in the wheels causes sharp blows to rack and twist the chassis structure, whereas the pneumatic tire absorbs a larger proportion of these shocks, and thus reinforces the spring action in relieving the chassis. There is, however, a reverse side to this, caused by the greater speeds which in spite of the generally larger sized wheels result in higher engine speeds. This sets up mechanical vibrations, which in conjunction with other troubles engendered by high engine speeds raises the proportion of trouble in this part of the mechanism. However, as stated before, the total amount of trouble is decreased, and this becomes more apparent when placed in proportion with the car mileage.

This is illustrated to some extent by the experience on a group of 1½ to 2 ton cars numbering about sixty, which are being operated on long distance transfer work. The mileage is running between 50,000 and 60,000 miles per year. The distances covered by each car range from 130 to 205 miles per day, this high daily mileage being made possible by properly regulating shifts for the men. Unfortunately there is no parallel service on solid tires to compare with, but it is the opinion of competent observers that the repair cost for these cars is 50 per cent of the probable cost on solid tires, and it is extremely doubtful if the work could be performed at all with solid tires on anywhere near the present schedule.

Reports from these cars indicate an extremely small amount of mechanical trouble in the axles and chassis. It is estimated that 75 per cent of the repair work is on the powerplant, and a considerable, if not the greater, proportion of this is due to the fact that the increase in speeds has not been accompanied by more care in following up lubrication, etc.

To anyone who has attempted to drive a vehicle on solid tires on any but roads in absolutely perfect condition, and particularly if the car was not loaded to a point where the springs were operating to their full extent, the limitations on speed are painfully apparent. The writer has driven a 3-ton truck on solid tires 165 miles at an average of 17 miles per hr., and as a result is prepared to discourage anyone from doing likewise with the thought in mind that the experience is pleasant. On pneumatic tires this would not be at all difficult. This ability to increase the speed of the vehicle materially increases the distances which can be covered, and is one of the most important advantages to be gained. As pointed out before, however, the gain will be limited if the proportion of idle time at terminals and delivery points is high, and this is one of the, at present, undetermined factors in predicting the degree of success which will follow the use of pneumatic tires on larger sizes of vehicles.

The question of relative gasoline consumption is not so easy to dispose of. Many claims are made as to increase in economy effected by use of pneumatic tires. Unfortunately, the supporting evidence in many cases is, to say the least, incomplete. Comparisons are made in some instances between vehicles of different makes, in others between vehicles of the same make but operating under dissimilar conditions, and so on. Any one who has attempted to collect accurate data on this subject can appreciate the large number of variables which can influence the results and will understand how hard it is to assign a value to each of these variables.

On the group of vehicles mentioned above the average of gas consumption for all the cars is very close to 35 gross ton-miles per gal. On this type of car with solid tires, 30 to 32 gross ton-miles per gal. is considered average performance. These figures are not directly comparable, however, for the reasons enumerated.

I have made some tests using the same car and nearly the same loads over a route of 272 miles, with average road conditions as to surface and gradients. The solid tires were 34 in. in diameter, and the axle gear reduction was such as to give 69.3 r.p.m. of the engine per mile per hr. of the car. The pneumatic tires were 38 in. in diameter and gave 62.7 r.p.m. per mile per hr. Three series of tests were made, one with solid tires, one with the pneumatics on the same axle reduction, and the third with the axle reduction altered to compensate for the increased tire size.

Runs were made with different loads; in the case of the solid tire one run was made with a considerable overload, which was not duplicated on the pneumatic tires. The results obtained are tabulated below:

Test number	Weight empty, lb.	Load, lb.	Total weight, lb.	Ton-miles per gal.	Total time in high gear, per cent
1[2]	4,500	525	5,025	30.33	89.1
2[2]	4,500	2,350	6,850	32.45	77.7
3[2]	4,500	4,175	8,675	36.35	62.7
4[2]	4,500	5,900	10,400	42.00	57.1
5[3]	4,500	680	5,180	28.20	81.3
6[3]	4,500	2,000	6,500	32.10	74.6
7[3]	4,500	3,580	8,080	31.96	62.1
8[4]	4,500	550	5,050	24.40	88.2
9[4]	4,500	3,480	7,980	27.40	63.0

These tests were made as carefully as possible and are, to say the least, disconcerting in the results shown. It is possible, and in fact very probable, that these results are due to the form of the tires, which were not of the conventional cross-section and were designed to operate at considerably lower inflation pressures than normal.

General observations lead me to believe that the performance with regard to gasoline consumption will vary according to the road conditions. On very good roads there will be little or no difference, while on bumpy roads the pneumatic tire will show up the better.

With regard to the claim for decreased oil consumption I can see no good reason for any change in this particular. If there is any difference I should think it would be to show a higher consumption for pneumatic tires, because on the whole the engine speeds will be higher, and as the wheel diameters are greater the engine will be required to develop high average pressures, that is, it will be operating at a greater throttle opening more of the time.

The decrease in strain and the resultant lessened fatigue of the driver is a very important advantage. It is difficult to assign a definite relative value to this feature, but it needs little discussion to realize that the efficiency of the machine is dependent on the efficiency of the operator, and anything which favorably affects the latter will be reflected in improvement in the former.

The question of the effect of heavy truck traffic on roads is one which is occupying a prominent place in the thoughts of those charged with their construction and maintenance. The claim is made that the pneumatic tire lessens the strain on roads caused by the larger sizes of trucks. On what this claim is based it is hard to say. There has not, up to the present time, been sufficient experience with pneumatic equipment on trucks of 3-tons capacity and over to give accurate data on which to base an opinion.

Observations made on the highways traversed by heavy truck traffic during the last eighteen months indicate that a large amount of the trouble was due to the failure not of the surface but of the foundations, and while it may be argued that this was in part due to shocks and vibrations, it is my opinion that the real reason was simply overload. Given a good road as to foundation and surface, and trucks operated at reasonable speeds with respect to their size, and I do not believe that any great difference in road depreciation will be found.

One very great advantage of the pneumatic tire is the greater adhesion possible, particularly with the types of so-called non-skid treads which have been developed. This feature has shown itself to be of great value, especially during the severe weather of last winter, when pneumatic tired trucks repeatedly demonstrated their ability to keep going, while solid tire equipment was in continual difficulty.

Objections to Pneumatic Tires

The objections to pneumatic tires are not so numerous but need careful consideration lest we be carried away with the idea that their use offers a solution for all troubles with no problems of their own needing attention. These objections are in my opinion:

(1) High initial cost compared with solid tires
(2) The need of carrying emergency equipment
(3) The difficulty attendant on making road changes due to weight and high inflation pressures required

[2]Solid tires.
[3]Pneumatic tires and the same axle reduction.
[4]Pneumatic tires and a changed axle reduction to compensate for the greater wheel size.

(4) Reduction of the high gear ability and limitation of the total ability due to larger diameter of wheels

(5) Limitations imposed on the size of brakes due to the small size of wheels

I have taken the data published in the issue of *Automotive Industries* previously referred to and determined the average solid tire equipment of trucks from 1 to 5 tons' capacity. By taking the tire capacities corresponding to these sizes, it is possible to select approximate pneumatic equipment and thus get an idea of the comparative initial cost of the equipment. The results obtained are given below in tabular form.

On the 1-ton size only one extra tire is figured in, as the front and rear ones are the same; for the other sizes two extra tires are figured. It is possible by increasing the size of the front tires on the 1¼ to 1½ ton class to have all tires alike, and this would in all probability be desirable.

Based on these figures, it will be seen that a material increase in tire mileage must be obtained to bring the cost per mile down to within a reasonable comparison with solid tires. Fortunately, this seems perfectly possible, at least up to 2-tons capacity. On the group of cars which has been used before in this article for illustration, the grand average of reported mileage to date is 14,000 miles. One make of tire has averaged 19,000 miles, and of all the tires none has given less than 6000 or 7000 miles.

This objection then resolves itself into a proposition of increasing the difficulty of getting the truck owner interested on account of the greater investment. To offset this, experience on cars up to 2-tons capacity at least, indicates that the longer tire life obtained, together with the compensating factors outlined above under the head of advantages, will pay a reasonable return on this increased investment.

The need for emergency equipment is a distinct handicap, not only from the standpoint of initial expense, but because of the difficulty in providing suitable place for carrying these large sized tires so as to be accessible and yet not encroach seriously on the cargo space or interfere with the operator when getting into the truck.

The question of road changes for punctures, etc., is a very serious item. While these troubles are guarded against in the tire construction and are reduced to a minimum, they cannot be eliminated and the penalty incurred by running on a flat tire is too great to be considered. The two bad features in this proposition are the weight of these tires and rims and the high inflation pressures required.

The weights are roughly as follows for an inflated tire and demountable rim: 38 by 7-in., 152 lb.; 40 by 8-in., 213 lb.; 44 by 10-in., 400 lb. These figures represent weights that require quite a bit of handling.

Inflation pressures recommended are: 5-in section, 80 lb.; 6-in., 90 lb.; 7-in., 100 lb.; 8-in., 110 lb.; 9-in., 120 lb.; 10-in., 130 lb., and 12-in. 140 lb. It is impracticable to consider hand pumping for any but the 5-in. size, and a mechanical pump to do the job is quite a piece of apparatus, and to be installed correctly adds another considerable item of expense which must be taken into consideration.

By referring to the table, it will be seen that the driving wheel diameters are increased as follows:

Capacity, tons	Old diameter, in.	New diameter, in.	Increase in diameter, per cent.
1	34	35	3
1¼ to 1½	34	36	6
2 to 2½	36	40	11
3 to 3½	36	44	22½
5	36	44	22½

On the smaller sizes the change is not so great and will probably work no material hardship except in cases where the brake equipment is on the transmission. With the larger sizes the difference is so great as to make it extremely doubtful whether there is sufficient flexibility in any well-designed truck to permit successful application.

The larger sections used in these tires together with the space taken up by the demountable rim leave a very small wheel diameter remaining, and this imposes severe limitations on the size of brake equipment and decreases the ability of the brakes at the same time. This is a very important matter, on account of the fact that the greater speeds put considerably heavier duty on the braking systems.

The heavy-duty pneumatic tire, particularly in the larger sizes, has come into prominence in the last few years when engineers were so completely occupied as to leave little time for the thorough investigation of the subject to determine what effect their use would have on future design. That there will be need of a considerable change in design with respect to some particulars seems very evident.

The increase in speed carries with it a demand for more efficient brake equipment. Whether the present style of direct-acting brake can be developed further to do the work on the larger trucks is a question which will have to be considered. Inasmuch as air pressure will be needed to inflate the tires, calling for an efficient air compressor, it may be found feasible to add the other

Truck capacity, tons	Solid tires front, in.	Solid tires rear, in.	Pneumatic tires front, in.	Pneumatic tires rear, in.	Increased cost pneumatic tires over solid, per cent	Increased cost pneumatic over solid including extra tires, per cent
1	34 × 3½	34 × 4	35 × 5	35 × 5	80	125
1¼ to 1½	34 × 3½	34 × 5	35 × 5	36 × 6	93	184
1¼ to 1½	36 × 3½	36 × 5	35 × 5	36 × 6	77	165
2 to 2½	36 × 4	36 × 7	36 × 6	40 × 8	110	216
3 to 3½	36 × 5	36 × 5 dual	36 × 6	44 × 10	87	180
5	36 × 6	36 × 6 dual	38 × 7	44 × 10	60	140

elements necessary to provide for the use of airbrakes.

Trucks as built at present have been developed for solid tires. The factors of safety in the load-carrying elements have been made sufficiently great to provide for the shock incident to their use. The gear ratios in axles and transmissions have been designed on the basis of the wheel diameters in common use. The thrust capacities of the bearings and the torsional strengths of axle, transmission and propeller shafts have also been calculated on these wheel diameters. Increasing the wheel diameters has created an entirely new set of conditions which must be investigated before the answer can be safely stated.

This does not mean that pneumatic tires cannot be used successfully with trucks as they are built today. They not only can, but are being so operated. It does mean, however, that particularly on the larger sizes, the truck engineer must recognize the new conditions which confront him and must prepare himself to meet them by making careful investigation on the subject and learning the relative importance of the items herein suggested and possibly others which have been neglected.

The statements made herein are exceedingly general in character. Experience on this proposition is apt to be so varied that exceptions to my deductions are likely to be numerous. If this is so and discussion is created which will throw more light on the subject, the purposes of the paper will have been fully served.

The Discussion

J. E. Hale:—Comparisons of cost between solid and pneumatic tires at this time are not really useful. When the tire makers have had a chance to get into volume production on pneumatic truck tires and down to bed rock in the matter of improving the quality on the one hand and eliminating expensive constructions on the other we shall be able to tabulate costs. There are one or two places where I think the sizes should be chosen differently. For instance, the rear of the 1-ton truck should be a 6-in. tire, and the rear of a 1½-ton truck should be a 7-in. tire. The rear of a 5-ton truck should be a 12-in. tire.

Pneumatic tire equipment for passenger busses has remarkable possibilities. It has already been used to a considerable extent and promises to open up the passenger bus field in the most remarkable and profitable way. A volume might be written on the enormous possibilities accruing from an increase in permissible speed. We who have had experience in operating trucks of all sizes up to 5 tons on pneumatics have come to realize that motor trucks, provided they have the power, can be operated at any speed within the bounds of safety. Another item is the control which the driver has over the truck. The freedom from skidding on bad streets is very noticeable.

Another advantage not at once apparent which should be regarded as the most important of all, is the increased radius of operation and all-round extension of service which is permissible on pneumatic-tired trucks. This is most important because of the fact that a truck with pneumatic tires can cover so much more ground particularly in inter-city haulage where, up to the present time, it has been inadvisable to use solid-tired trucks.

The five objections to pneumatic truck tires which Mr. Bachman mentions, while legitimate notations on this subject, will either disappear entirely or be greatly diminished in importance by improvements in the tires and the redesign of the trucks themselves to accommodate any kind of tire equipment.

S. P. Thacher:—The advantages of pneumatic tires for trucks, which Mr. Bachman lists as claims and of which he says some are open to question, have been so thoroughly substantiated by data which I have collected in the past 8 months, that there should no longer be any doubt in the minds of truck engineers that their brothers in the tire industry will make possible, as they have for the passenger car, any and all truck performance characteristics which fall in the sphere of tire problems.

FOREIGN ROADS AND THEIR MAINTENANCE

At a meeting of the Motor Truck Association of America held Feb. 13 at the Automobile Club of America, New York City, the guest of honor was David Beecroft, managing editor, Class Journal Publishing Co. Mr. Beecroft has recently returned from a trip to Europe to collect data on the use of trucks, automobiles, tractors, trailers and other products of the automotive industries in the war and after the armistice was signed. In connection with this work he secured considerable information on the condition of the roads and the matter of their upkeep.

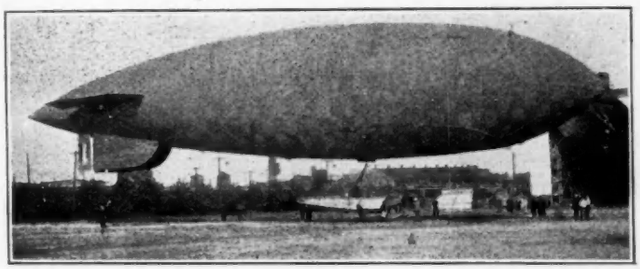
In stating the results of his observations Mr. Beecroft said among other things: "The system of road maintenance during the war was so complete that shell holes caused little disturbance to highway transportation in view of the fact within 15 min. after their creation they were filled and the road repaired. The utmost importance of good roads was manifested by the abundance of road material along the highways and the ceaseless activity of squads of men engaged in repairing the roads. It was ever apparent that good roads were instrumental toward the successful operation of the allied armies and very often victory resulted through the rapid reconstruction of damaged roads, thus enabling the transportation of immediate necessities. Particular tribute is due the boys who operated the fleets of trucks and who alone carried the needed ammunition to batteries when the country was in an utterly impassable condition. The morale of the drivers and their assistants was splendid. Day after day nothing but fleets of trucks, sometimes numbering over 200, were to be seen, and their neat and splendid appearance was indeed exceedingly interesting, especially when the circumstances under which they operated were taken into consideration. Another feature of interest was the efficient manner in which the operation of fleets was carried out. The minutest detail was not overlooked, and the manner in which fleets were despatched was similar to our railroad method. Owing to the constant changes in position on the firing line it was always necessary to keep men posted along the highways to advise fleet commanders when the destination of their convoys was changed, thereby preventing the destruction or capture of the fleet. To avoid congestion, notices were posted along the roads indicating the speed with which trucks should be operated on particular stretches. It did not matter whether a truck was of past or modern design if it could carry excess tonnage under pressing conditions and the mechanism was accessible for quick repair. Many points of interest concerning the handling of traffic, the upkeep of roads, etc., are to be learned from the war."

The Case for the Airship

By Ladislas d'Orcy[1] (*Member*)

Aeronautic Meeting Paper *Illustrated with* Photographs

In stating the case for the airship it is really impossible to give the subject an adequate defense without entering into a controversial discussion with the advocates of heavier-than-air machines. Although the features of airships and airplanes are so widely different



Tractor "Blimp," Built by the Goodrich Co. for the U. S. Navy and Equipped with One Curtiss OXX 100-Hp. Engine

that each type of aircraft promises to cover quite different fields of usefulness, the impression prevails at large that the airplane will eventually displace the airship, be it for military or commercial purposes.

This wholly erroneous impression does not take into account the extraordinary development that has taken place in airship construction in the last four years, which has been kept even more secret than airplane progress.

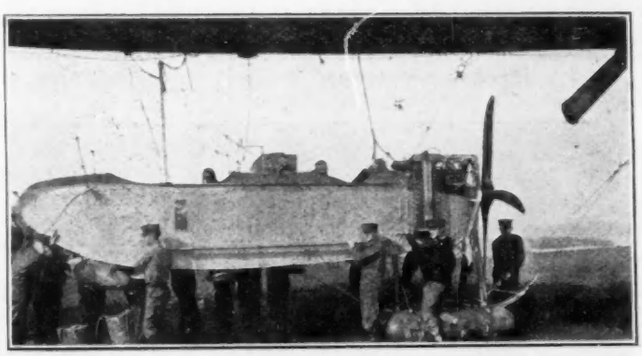
Progress Made Since 1914

Before discussing the more general problems of lighter-than-air craft with respect to their possible use in times of peace and war, some figures will be given to show at once the great progress realized in this domain during the Great War. As Germany was, at the signing of the armistice, still leading in airship construction, though closely followed by Great Britain, two German naval Zeppelins, the L3 and the L71, will be taken as representative of the stage of progress in 1914 and in 1918.

From the L3 to the L71 the gross, or total, lift has increased from 30 to 66.64 tons; the disposable lift, or useful load, from 8.5 to 38.84 tons; the efficiency ratio, that is, the ratio of disposable lift to gross lift, from 27.3 to 58.3 per cent; the total horsepower, from 800 to 2100; the full speed at 10,000 ft., from 50 to 77.6 miles per hr.; the cruising endurance, at 45 miles per hr., from 20 to 177½ hr.; and the static ceiling, that is, the altitude that can be reached by purely static means, from 6000 to 21,000 ft.

The most impressive of the above figures are, to my mind, the ones showing the increase in efficiency ratio, which has about doubled with the twofold increase in capacity of the Zeppelin, for this well illustrates the one very important feature of lighter-than-air craft which confers upon them a superiority over heavier-than-air craft, namely, that an increase in the size of airships

Pusher "Blimp," Built by the Goodyear Co. for the U. S. Navy, Equipped with One Thomas 150-Hp. Engine



Car of the Goodyear Pusher "Blimp"

gives greatly improved efficiency. In airplanes, on the contrary, efficiency not only remains stationary with the sizes now reached, but is even likely to decrease with further increases in size. At the present time the best all-round British airplane, the DH-10a, with two 400-hp. Liberty engines, has an efficiency ratio of 36.1 per cent. This machine has a high speed, at 10,000 ft., of 125 miles per hr., a cruising endurance of 14 hr., a ceiling of 19,000 ft., and a useful load of 1.45 tons. As against this performance the best all-round airplane of 1914, the two-seater 80-hp. Avro, with an endurance of 4 hr., showed an efficiency ratio of 36.3 per cent, so that there has actually occurred a slight loss of efficiency, and it

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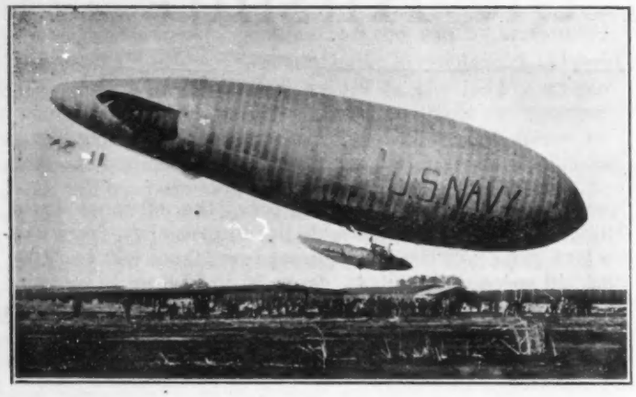


COASTAL AIRSHIP OF THE U. S. NAVY, BUILT BY THE GOODYEAR CO., AND DRIVEN BY TWO 150-HP. TWIN-SCREW HISPANO-SUIZA ENGINES

can be said that this would have been greater but for considerable improvement in design.

The reason why in an airship the efficiency ratio is improved with an increase in size, whereas in the airplane it remains at best stationary, is due to the fact that the airship derives its lift from volume, while the airplane derives its lift from area. Now, in either case what may be termed the unit of lift, cubic feet of volume or square feet of area, exerts only a definite lifting effect; in the airship this is determined by the specific gravity of hydrogen or helium, and is therefore immovable, whereas in the airplane it depends upon progress in design, and is thus still open to improvement. This fact may, in a certain measure, work out in favor of the airplane, but there are other factors which actually limit the practicable size of heavier-than-air craft.

One of these is that while the lift of an airplane theoretically varies with the square of linear dimensions, the weight of the wing structure per unit of area does not remain stationary with an increase of wing area, but increases, because the larger wing structure must be made proportionally strong. Consequently, a size is eventually reached where every additional square foot of surface weighs as much as it can lift, so that beyond this size there will occur a marked reduction in efficiency.

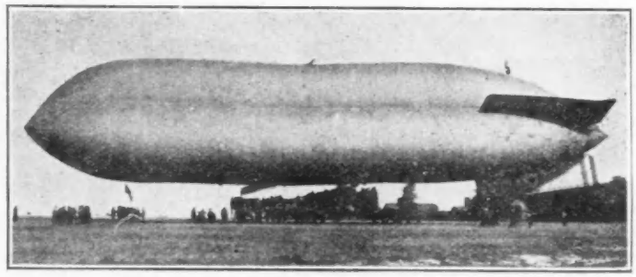
Now we know that the strength of similar structures is inversely proportional to their linear dimensions. This rule applies equally to airships and airplanes, but while the lift varies as the cube of dimensions in lighter-than-air craft, and as the square in heavier-than-air craft, an increase in lift is attained in airships with much less increase of dimensions than in airplanes. For instance, if we double the span, and, to retain the same aspect ratio, the chord of a given airplane, the lift will increase four times, while theoretically the weight will have to be eight times as great if we want to obtain the same structural strength. But in an airship, when we increase the lift four times, we increase the length of the structure only by the cube root of four, that is, approximately one and a half times, so that the weight of the structure will be only four times greater for the same proportionate strength, which is to say that the weight of an airship is, for the same structural strength, directly proportional to the total lift.

Now, it is true that, as heavier-than-air advocates contend, the law of geometrical similitude is not strictly applicable when aircraft are increased in size, because more suitable materials become available for constructing large machines, or else, available materials can be used in a more advantageous form. However, this rule applies to lighter-than-air craft as well as to heavier-than-air types; and it must be conceded that even with allowance for improved efficiency due to more suitable materials of construction, the weight of an airplane *does* increase in a greater proportion than the lift, at best like 3 to 2, always provided the same structural strength is desired.

Another technical advantage afforded by the airship is that the so-called coefficient of tractive resistance, that is, the ratio of the weight of machinery to total lift, obviously decreases with an increase of size, because the lift varies as the cube of the linear dimensions, while the resistance of the air and the brake horsepower vary as the square of the dimensions, all other things being equal.

The British National Physical Laboratory has made an exhaustive investigation of the tractive resistance of airship hulls, as the result of which some highly interesting figures are now available. These are based on the streamline hull of the Zeppelin L33, which was brought down in England in the fall of 1916. It appears from these figures that the tractive resistance decreases in a marked degree with an increase in size and a *proportionate* increase in horsepower. Thus the coefficient of tractive resistance of a 60-ton rigid, which is about the largest size in existence, is 1.9 per cent at 45 miles per hr., 3.8 per cent at 60 miles per hr., and 7.7 per cent at 80 miles per hr., as against that of a 300-ton rigid, which is 0.9 per cent at 45 miles per hr., 1.8 per cent at 60 miles per hr., and 3.6 per cent at 80 miles per hr. In other words, a 300-ton rigid can fly more economically at 80 miles per hr. than a 60-ton rigid can at 60 miles per hr.

This explains why the performance of the latest Zeppelins, which have almost trebled in size since 1914, has so marvelously improved. One such performance, which has recently been made public by the British Air Ministry and cannot, therefore, be taken for enemy propaganda, fittingly illustrates the tremendous possibilities of the large rigid airship in long distance aerial transport. In the fall of 1917 the German Admiralty ordered one of its airships to undertake a relief expedition in behalf of the German force that was surrounded by the Allies in East Africa. Accordingly the naval Zeppelin L59, after having been loaded up with some 20 tons of munitions and stores, left Jamboli, Bulgaria, at 8:35 a. m., Nov. 21, heading for East Africa. The airship proceeded as far as Khartum, Egypt, which she reached in the early morning of Nov. 23, when she received a radio message from the German Admiralty, ordering her to return, as the force to be relieved was reported to have surrendered. The L59 thereupon put back to Jamboli, where she arrived without any untoward incident on the morning of



BRITISH COASTAL AIRSHIP, ASTRA-TORRÈS TYPE, WITH ONE 110-HP. BERLIET ENGINE FORWARD, ONE 260-HP. FIAT ENGINE AFT, ONE TRACTOR AND ONE PUSHER AIRSCREWS

Nov. 25, having covered in the course of her 4-day cruise a distance estimated at 4500 statute miles or 7300 km.

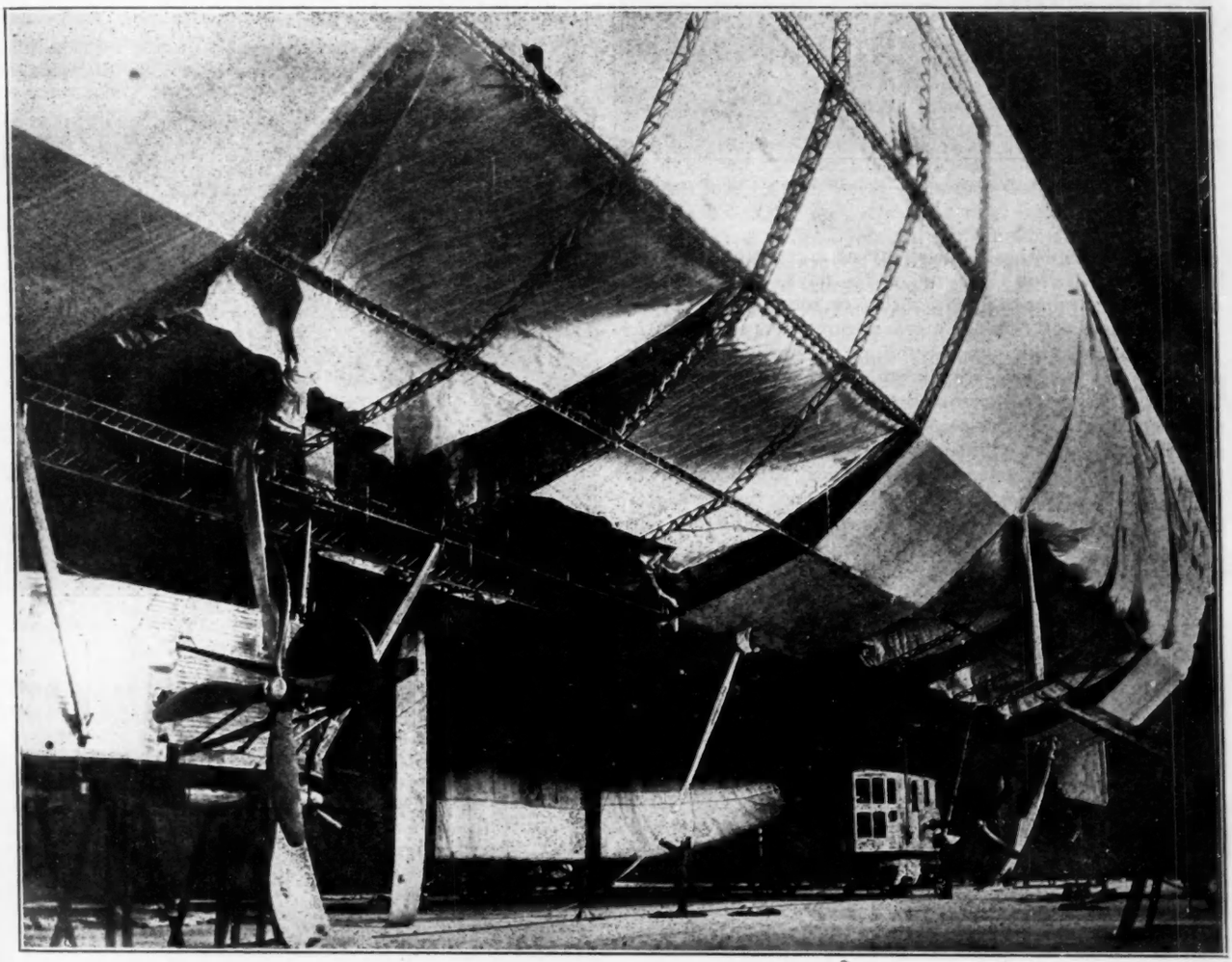
Possibilities of Long Distance Flight

As the shortest distance between America and Europe, from St. John's, N. F., to the southwest coast of Ireland, is somewhat less than 2000 English miles, it is obvious that an airship of the L59 class could, with the crew of twenty-two and some 20 tons of cargo she carried on that memorable cruise, easily cross the Atlantic both ways without even refuelling. In view of such a voyage the best airplane performance naturally dwarfs to a considerable degree; nor is there anything extraordinary in the report that the Zeppelin Co. is engaged in building an airship of 115 gross lift tons and 2400 hp., which will carry 100 passengers, 45 tons of cargo, and 30 tons of fuel and provisions across the Atlantic, of course if Marshal Foch will permit it.

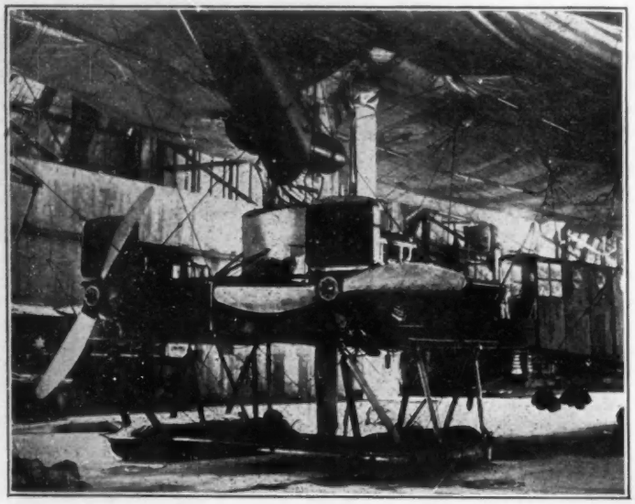
But it does not seem likely that we will have to wait for a German airship to open up the aerial route across the Atlantic, for some recent information at hand tends to show that a British rigid airship will attempt this venture as soon as favorable weather sets in, that is, sometime in the coming spring.

I now propose to answer some of the principal objections which are made against the use of airships in passenger transportation, for I do not think anyone familiar with the subject can deny their great potentiality as a military weapon since American chemists have successfully overcome the problem of producing a non-inflammable lifting gas, helium, in large quantities and at a comparatively low cost. One of these is that the comparatively low speed of airships makes these craft less independent of adverse winds, and, therefore, less reliable in operation on a schedule than the airplane. Airships have not yet exceeded a speed of 80 miles per hr., whereas airplanes have made speeds of over 150 miles per hr., from which the inference is naturally drawn that heavier-than-air craft will prove much more reliable and advantageous as time-savers in aerial transport than lighter-than-air craft. Arguments of this sort are, however, highly misleading, because speed alone cannot be considered the sole criterion of commercial utility; in considering aircraft for the purpose of transporting passengers and freight the element of speed must be jointly examined with the load carried and the cruising radius.

Referring again to the figures given before, it appears that the best existing all-round airplane, the DH-10a, can fly at a speed of 125 miles per hr. for 14 hr., that is, in still air, over a distance of 1750 miles; while the best

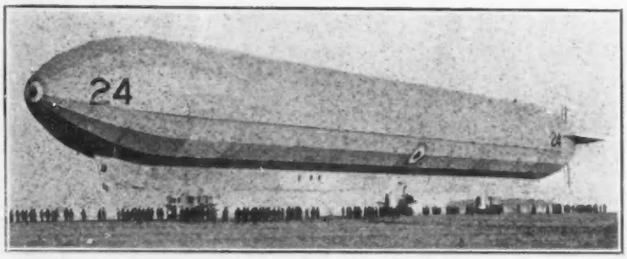


Portion of the Hull of the British Rigid R29 After Some Sections of the Outer Cover Have Been Removed to Show the Gas Bags
The Absence of the External Keel Is Notable, the Gangway Being Fitted in the Bottom of the Hull



AFTER PORTION OF THE CAR, AND ENGINE INSTALLATION OF THE NS7

existing airship, the L71, can fly at a cruising speed of 45 miles per hr. for 177½ hr, or 7½ days, that is, in still air, over a distance of 7987.5 miles, or roughly 8000 miles. A comparison of these figures strongly emphasizes the point that the airplane is mainly a high-speed short distance carrier, while the large, rigid airship is essentially a medium speed long distance carrier; either type of aircraft has therefore its well appointed sphere of activity in aerial navigation. Airships can be employed to best advantage on routes exceeding 1000 miles in length, while airplanes will prove useful on trips of shorter distances, where the time employed in putting off and taking on passengers and in refuelling would curtail the saving of time effected by aerial travel.



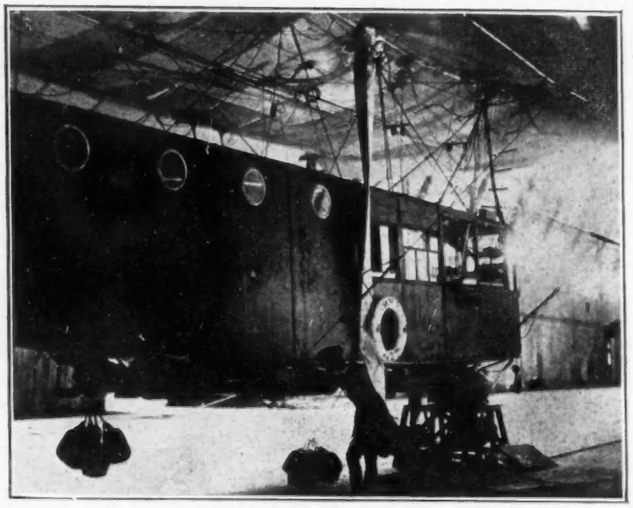
THE BRITISH RIGID AIRSHIP R24, A VESSEL OF PRE-WAR ZEPPELIN TYPE, NOTABLE FOR ITS EXTERNAL KEEL

FIELDS OF AIRPLANES AND AIRSHIPS

It has therefore been suggested that airships should mainly be employed in transcontinental and transoceanic traffic, while airplanes could be used for feeding the airship terminals with passengers hailing from places several hundred miles distant. In this way the airship would compete with the steamship, and the airplane with the railroad train; the saving of time would in either case amount to at least 50 per cent.

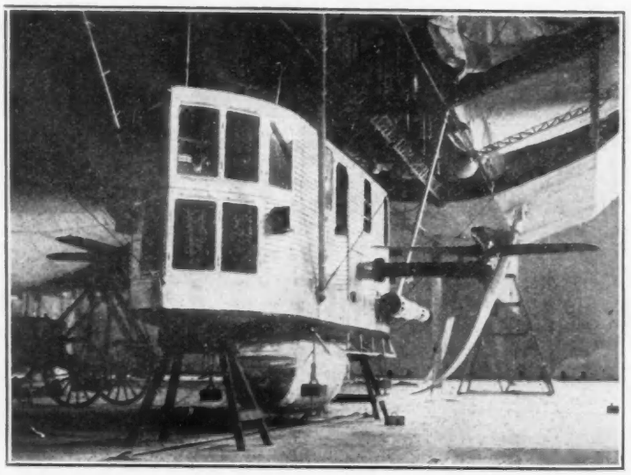
The great endurance and cargo capacity of airships are not, however, the only features that make them particularly desirable for the long distance transportation of passengers and freight. One of the important points in favor of lighter-than-air craft is that they afford a decidedly greater element of safety than heavier-than-air craft, because an airship can stay aloft regardless of engine failure, whereas a stoppage of the airplane's powerplant necessitates an immediate descent in gliding flight. Now, there is no inherent danger in such a descent, provided suitable landing grounds are available at given distances; but until a chain of numerous landing stations is created along the lanes of future aerial travel, some risk will be involved in public transportation by airplane, especially over wooded and marshy country and over the ocean. It is in transoceanic traffic that the greatest future of the airship seems to lie, because there competition with the existing means of transport will be much easier owing to the low speed of steamships, if compared to railroad trains, and because alighting in a stiff gale is not at all pleasant to visualize.

Still another factor which seems to favor lighter-than-air craft in public transportation over long distances is



FORWARD PORTION OF THE CAR OF THE BRITISH AIRSHIP NS7 (NORTH SEA CLASS). Note Bombs Carried under the Floor

that the requirements of comfort can be attained much easier than on heavier-than-air craft. First of all, weight is, comparatively speaking, a matter of minor importance on airships because of their great buoyancy; and secondly, the large size of the hull affords better opportunities for fitting not only spacious state rooms, lounges,



THE AFTER CAR OF THE R29, WITH ITS SWIVEL-MOUNTED AIRSCREWS

etc., but of fitting them so that they will be sufficiently removed from the engines and airscrews to actually suppress the resulting vibration and noise. Furthermore, a promenade deck of several hundred feet in length can be provided on top of the hull. All these may seem minor matters, but they should not be overlooked, for the mere saving of time will not attract a large section of the traveling public to aerial transportation unless a sufficient amount of comfort be afforded as well.

Position of United States on Development

The question now arises, since the value of airships for commercial purposes seems to have been sufficiently outlined, where does this country stand in the development of lighter-than-air craft? To date only small size non-rigid airships have been built in the United States, and this exclusively for the needs of the Navy. These vessels subdivide into two classes, the so-called "Blimps," or submarine scouts, and the Coastal, or C-class ships; the former have a capacity of about 100,000 cu. ft. and a single engine of 100 to 150 hp., driving a tractor or pusher screw, while the latter displace about 200,000 cu. ft. and are driven by two 150-hp. engines and twin screws. Although both types are adaptations of British designs, various improvements have been introduced in these ships by American manufacturers, particularly in the development of the larger type, which may be considered as a distinctly American product. This is especially noticeable in the rigging of the car to the hull, which is of the finger patch system on the American Coastals, whereas in the British C-class vessels the car is rigged to an internal "rope girder" which is kept in tension by the tautness of the hull. This rope girder is of triangular form in transverse cross-section, the apices of the triangles being secured to the intersection lines of the three-lobed hull.

A larger type of non-rigid airship, which the British have developed for scout work with the fleet, is the North Sea class. These ships have a capacity of 360,000 cu. ft., two 260-hp. engines, and a full-speed endurance, at 57.5 miles per hr., of 20 hr.; they carry a crew of ten. So far no corresponding type has been produced in this country, and the same remark applies to the large rigid ships Great Britain has been developing with great steadiness since the war. One of these vessels, the R33, which is reported to be awaiting the completion of certain arrangements prior to attempting to cross the Atlantic, has a capacity of 2,000,000 cu. ft., five engines giving a total horsepower of 1250, and a full speed of about 70 miles per hr.; her crew numbers twenty.

In a report recently made to Secretary of the Navy Daniels on the aeronautical needs of the Navy Admiral Mayo pointed out that the latest British rigids possess an endurance of well over 200 hr., which would give them a range "safely across the Atlantic and return in any weather except the worst storms." Therefore the construction of four rigids, each to cost $1,500,000, was recommended and due provision has since been made for this purpose in the Naval Appropriation Bill.

While the Navy has, since the war, been in the van of lighter-than-air development, it would seem desirable that American engineering firms also pay some attention to this phase of aeronautical progress, particularly as regards the construction of rigid airships, that a repetition of the aerial unpreparedness which characterized this country two years ago may be prevented in case of future emergencies. Since a non-inflammable lifting gas has become available, of which the United States possesses an almost unlimited supply, the airship promises to play in future conflicts a much more important rôle than in the Great War, great as this has been. But even if future wars should be made impossible, the United States will need a large fleet of rigids for the demands of fast long distance transport, unless, of course, this country prefers to see this traffic go to air ships flying foreign flags.

RESISTANCE DUE TO NOSE RADIATOR

AERONAUTIC Power Plants Report No. 24, which is a preliminary one, considers the effect of placing a radiator in the nose of a fuselage as compared with locating one possessing the same core construction and having an equivalent cooling capacity in the free air, and streamlining the nose of the fuselage. The results of these tests indicate less difference than would be shown by comparing those obtained with radiators specially selected for each of the positions in which they were placed. They are qualitative only, but are so striking as to indicate that the nose of the fuselage is not a desirable location for a radiator from the point of view of head resistance.

A model fuselage 60 in. long, 10 in. wide and 13 in. high was constructed with a removable streamline nose, which, when taken out, allowed a section of radiator core 8 in. square to be placed in the nose. Two holes on each side of the fuselage, each about 1½ by 6½ in., were cut about 1 ft. back from the nose and fitted with adjustable sliding doors. By opening these vents the amount of air passing through the nose was varied. The model was mounted in a 54-in. wind tunnel and the head resistance measured under the following conditions:

(1) Streamline nose on model. No change in resistance was observed whether vents were open or closed.

(2) Streamline nose removed, but nose radiator covered with a sheet of paper so that there was no air flow through the core.

(3) Nose radiator in place with varying amounts of air flow controlled by opening the vents. Seven or eight different air speeds were tried in each case, the maximum being about 70 miles per hr.

These tests gave the following qualitative results:

(1) At any given plane speed the total resistance of a fuselage with a flat nose radiator is increased by augmenting the air flow through the radiator, either by opening exit vents for the air or by decreasing the resistance of the radiator to the passage of air. This shows that a nose radiator, in contradistinction to a free air radiator, should be of compact construction with high heat transfer for low air flows through the core, requiring therefore a core of high resistance.

(2) With varying plane speeds the relative efficiencies of free air and nose radiators do not change.

(3) With all three widely differing types of core tried, the combined resistance of the fuselage and a free air radiator of given cooling capacity was from 10 to 50 per cent less than that of the fuselage with a nose radiator of the same core construction and equivalent cooling capacity.

From other experiments performed at the Bureau of Standards it is clear that there is more chance for improvement in types of core for free air positions than in types of cores for the nose position.

The Story of the United States Standard Truck

By J. G. Utz,[1] (*Member*)

Annual Meeting Paper

IT is interesting to note the historical fact that the British Army first used motor trucks in 1903, thus giving them eleven years' experience to guide them when they entered the war in 1914.

The first use of motor trucks by the United States Army was in January, 1912, when two 1½-ton trucks were purchased by the office of the Quartermaster General for the purpose of testing them out and determining their fitness for military use. From results obtained in these tests, later in this year Lieut.-Col. C. B. Baker began to prepare specifications for the purchase of motor trucks for the army after having first communicated with several manufacturers and secured their suggestions and recommendations.

On May 7, 1913, the first specifications for 1½-ton trucks for U. S. Army use were issued, and from these a very few trucks were purchased. These specifications were revised and reissued on March 31, 1915. About this time the Society of Automobile Engineers, inspired by the use made of motor vehicles by the combatants in the great world war, began to take active interest in the use of motor transport for military purposes, and some correspondence passed between Past-presidents Dunham and Coffin in regard to the Society offering the Government its cooperation, not only in the preparation of specifications, but in the survey of the industry and automotive equipment already in use, with a view to the organization of such for military use should emergency arise.

On April 28, 1916, Colonel Baker, then chief of transportation in the office of the Quartermaster General, wrote the Society announcing the intention to issue revised specifications which would include both 1½ and 3 ton trucks, and requested the Society to cooperate in the preparation of these specifications. Colonel Baker was no doubt inspired by his memories of '98, when the Spanish War broke out, and the Transportation Division of the Quartermaster Corps, had to rush into the open market and purchase a heterogeneous lot of wagons, with all the attendant difficulties of keeping them in repair. Incidentally, Colonel Baker was instrumental in standardizing the mule-power army escort wagon, which today has simplified the interchangeability of wheels and other parts. It was not until about 1906 that all the non-standardized wagons purchased in 1898 were worn out and the U. S. A. escort wagon remained the standard.

The First Conference

On May 8, 1916, the Society, in cooperation with the National Automobile Chamber of Commerce, invited about fifty truck manufacturers to send their engineers to the offices of the Society for the purpose of complying with Colonel Baker's request. This meeting was presided over by the late Henry Souther, then consulting engineer for the Signal Corps, who acted for President Huff of the Society. After a broad discussion by the entire body, a representative committee of truck engineers was formed for further cooperation with Colonel Baker. This committee consisted of the engineers of five companies manufacturing trucks, five companies assembling trucks, and an engineer of a truck factory not making the type of truck being deliberated upon. The members of this committee were as follows:

A. L. Riker	Locomobile Co. of America
H. D. Church	Packard Motor Car Co.
W. R. Strickland	Peerless Motor Car Co.
John Younger	Pierce-Arrow Motor Car Co.
L. P. Kalb	Kelly Motor Truck Co.
B. B. Bachman	Autocar Co.
G. W. Smith	Nash Motors Co.
W. T. Norton	Selden Motor Vehicle Co.
E. R. Whitney	Commercial Truck Co. of America
A. J. Scaife	White Co.
F. A. Whitten	General Motors Truck Co.

The committee went into session on the same day with Colonel Baker and W. M. Britton, engineer for Colonel Baker's office, taking up various points in the specifications which Colonel Baker submitted. On account of the limited time, very few changes were made in the specifications as presented, and they were issued in June, 1916.

About this time the Government placed rush orders for the first large quantities of trucks that it had used. These were for use on the Mexican border, and the bulk of the orders were given to about four companies, they being chosen, evidently, according to their ability to make rapid deliveries. This fact is peculiarly interesting, as it was with these trucks that the officers of the army obtained their first large-scale experience with motor transportation. These trucks operated under most severe conditions, due to lack of roads, lack of organization, and unfamiliarity of officers, drivers, etc., with motor problems. This service constituted the most severe test to which trucks could be put on so large a scale.

Thus we should thank Francisco Villa for the beginning of the Motor Transport Corps of the U. S. Army. Fairly complete data were collected of the performance of these trucks, giving an interesting record of the shortcomings of commercial vehicles in army service.

On July 31, 1916, there was a meeting of the General Staff Committee on Motor Transportation with representatives of the automotive industry. Several of them were prominent members of this Society. At this meeting the subject of motor transportation was discussed in a very broad way; the matter of types of vehicles, the sources of supply, specifications, organization of truck companies, training of drivers, mechanics, etc., being

[1]Director of engineering, Standard Parts Co., Cleveland, Ohio.

gone into. It is not known just what resulted from this meeting, but it is considered one of the important steps in the cooperation between the army and the members of the automotive industry.

The Military Truck Committee of the Society, which had been appointed on May 8 to cooperate with Colonel Baker in the preparation of military truck specifications, was later formed into the Truck Standards Division of the Standards Committee, its principal function being continued cooperation with the Government in this work. This committee continued to hold meetings from time to time, preparing an ideal military truck specification which they intended to submit to army authorities. On Oct. 13, 1916, tentative specifications were submitted to the Standards Committee for criticism, and these were discussed and revamped at several meetings following this. On Jan. 5, 1917, a conference was held between the Motor Transport Committee of the War Department and two chosen representatives of the Truck Standards Division. At this meeting there were discussed certain fundamental matters of the specifications under consideration, based on Mexican border experiences.

Preparation of New Specifications

A little later, Colonel Baker informed the Society that a new set of specifications was being prepared by his office taking into consideration recommendations of the Truck Standards Committee, as expressed in the tentative specifications submitted by that body. He asked that the members of the committee meet him in Washington on March 19 and 20, for the purpose of discussing and criticising these specifications before they were issued. This meeting was held on the date mentioned, at which were present not only the members of the Truck Standards Division, but also General Manager Clarkson and the chairman of the Standards Committee. The specifications were discussed at as great length as time would permit. Members of the Truck Standards Committee took some strong exceptions to certain points, Colonel Baker overruling some of the exceptions and concurring in others. Following this conference there were published in May, 1917, Standard Specifications for Class A and Class B gasoline motor trucks. These specifications, while going into great detail, call special attention to the following fundamental items, which were considered of vital importance for military trucks.

(a) Low gear reduction
(b) Large size engine
(c) Four-speed transmission with very low first speed
(d) Maximum ground clearance
(e) Demountable tires of specified size and composition
(f) Large gasoline tank
(g) Electric lighting system
(h) Three-point engine suspension
(i) Locking differential
(j) Best quality alloy steel springs
(k) Gage of wheels
(l) Large radiator

These specifications called for some radical features of design which could not be made in existing models of trucks. However, it had been stated a number of times by Colonel Baker and other representatives of the War Department that it was not the intention to work a hardship on the motor truck industry, but that the specifications would be considered an ideal which would be worked toward when time should permit. At a meeting on April 6, at which were present Secretary of War Baker, Col. C. B. Baker, representing the office of the Quartermaster General, and officials of the National Automobile Chamber of Commerce, this principle was restated, and it was announced by Colonel Baker that he was anxious to arrange for motor vehicles in such a way that it would disturb as little as possible the general routine work of the automobile factories. It was also stated that early requirements would be cared for with present types of trucks, preference being given to those most nearly conforming to the printed specifications.

In the light of the past eighteen months' experience, some of the features of these specifications may seem somewhat ill advised, but it must be remembered that at that time our sum of knowledge in regard to military motor transportation was very much smaller than it is now, and the experience then in the possession of our army had all been gained on the Mexican border, which, we know now, furnished quite different conditions from those that obtained on the western front, until the last few weeks of the war furnished some bad road conditions. Although there were a number of engineers who disagreed with the specifications, their arguments were offset by the fact that no one knew on just what front the United States would be forced to fight, and it was considered advisable to issue specifications calling for a truck able to meet the most severe conditions, whether in Russia, Macedonia, Italy or France.

It has since been found that some of the fundamental principles of these specifications were based on incorrect premises. Nevertheless, it can be stated without fear of contradiction, that the May, 1917, specifications were the best of any yet produced, and marked a very great step in the way of cooperation between the army and the automotive industry.

About this time we declared war on Germany, and an inventory found our army possessed of about 2400 trucks. The army was confronted with the need of adequate motor transport and its twin problem of immediate procurement.

Production Difficulties

Immediately after the issuing of the specifications a number of truck manufacturers took steps to produce trucks which would meet the most important if not all the detailed requirements called for therein. Those companies producing all of the component parts of their own vehicles found this no insurmountable task, but those organizations buying all or part of their major units were met by the fact that none of the parts companies had produced or were contemplating the production of parts to meet the specifications. Since the contemplated requirements of the army were going to be so great that a large number of different makes of trucks, with the attendant repair difficulties, would have to be purchased, it was evident that some degree of standardization had to be effected, or the repair parts depots in France would be swamped. Since the Society has always been the exponent of standardization and presented the only clearing house for automotive engineers, it necessarily followed that it should be called upon by different members for assistance. After a number of inquiries had been received by the various engine, axle and transmission makers, they, of course, became very much interested in this proposition, and a large number of requests for information as to how best to meet the specifications were received by the Society.

On May 3, at the Quarterly Meeting in Cleveland, the Standards Committee ratified these Quartermaster Corps specifications, and so advised Colonel Baker in a letter prepared on that date and signed by the Chairman of the Standards Committee and General Manager Clarkson. At that time a meeting of the newly formed Trans-

mission Division was held, at which the principal topic of discussion was proper means and steps necessary to be taken in order to meet the Government specifications. On May 14, 1917, a meeting of the Truck Standards Committee was held in Washington to discuss special features called for in the specifications, such as bumpers, towing hooks, air cleaners, magneto brackets, etc., which, it was felt, should be standardized and made interchangeable between the various trucks then being developed to meet the specifications.

On June 2, 1917, a meeting of transmission makers and engine makers, as well as of the engineers of a few truck factories, was held in the Society rooms at Washington for further discussion of means for meeting the specifications. These discussions at once disclosed the effect that the work of these two groups would have on all of the other parts of the trucks, and on June 14, 15 and 16 further meetings were held at the Willard Hotel in Washington, at which were present representatives of the axle, universal-joint, radiator, bearing, frame and spring makers. Practically from the first of these meetings the possibility of effecting some degree of standardization or interchangeability was realized. Some of the transmission makers, especially those who had not previously produced truck transmissions, were in favor of a complete interchangeable design, while the makers of the other important units, as well as a good proportion of the transmission makers, favored only the interchangeability of entire units. In other words, the object was for each parts maker to design and produce his product in such a manner as to make it possible to replace one make with another.

This was at that time considered the logical course, as it did not affect the equipment and tools of various parts manufacturers to so great an extent as complete standardization would have done; further, it gave some of the main advantages of complete interchangeability without limiting the parts maker and depriving him of the possibility of improving his product. It can be seen that up to this time the matter of standardization had sprung up almost spontaneously as a direct result of the May specifications. It is not believed that at that time anyone, unless it were Col. Baker, had any idea that this work would lead to the complete design and the standardization of the military truck. The part which the Society had played was merely that of an agency bringing together the various engineers, helping to coordinate their work and to assist in enlightening all of the manufacturers of trucks and parts in the best way to meet the specifications.

Society Discusses Standardization

At the summer meeting of the Society, held in Washington on June 25, 26 and 27, the motor truck standardization proposition had assumed considerable proportions, and whereas in previous meetings all of the engineers had been divided into groups considering the various parts, with whatever truck engineers that were present acting as free lances, giving advice to all of the committees, at this meeting an organization of the truck engineers was effected. It was considered that the work of the various parts committees had proceeded far enough so that the general layouts and designs of the chassis could be made. The work up to this time was mainly on the 1½-ton size truck, but the larger size was always kept in mind and records kept of all the progress on anything which would apply to the larger model.

At this Washington meeting there were present a number of the engineers of the so-called old-line truck builders, and some concerted opposition to the program was offered by them. At one of the meetings the spokesman for this group, John Younger, objected to what he called piecemeal standardization, and advocated the complete standardization and design of all parts of the vehicle. He offered to give the benefit of his experiences in any such effort as this. The next meeting was held in Columbus, Ohio, on July 9, 1917, at Ohio State University. The meeting had assumed much larger proportions by this time, and the chassis committee had reached such a size that it was found necessary to effect a permanent organization and arrange for meetings to be held separately from the other groups. A meeting of this committee was held July 17, 1917, in Detroit, and good progress was made in settling some of the fundamental principles of chassis design.

The work of all the committees had progressed to such an extent that it was thought that one more meeting would be sufficient to wind up the entire matter, and that it would then be possible to put the work of all the committees down in black and white and issue a manual or specification by which all parts makers or truck assemblers would be guided. This meeting was called for July 20, 1917, at Columbus, Ohio. Not only were the members of the various committees invited to this meeting, but a special invitation was given also to at least sixty truck manufacturers to have their executives present, and a free discussion was requested. On the day previous to this meeting, the representatives of some of the old-line builders met at the Deshler Hotel in Columbus, and discussed the situation as it seemed to affect their companies. It was the consensus of opinion of all those present that it would be a dangerous experiment for the Government to proceed with the program, and George Graham of the Pierce-Arrow Motor Car Co., was chosen as spokesman to present their views to the meeting to be held on the next day.

In the meantime, the members of Col. Baker's office staff had a vision of a 100 per cent standardized truck —in other words, a complete new vehicle to be designed in the War Department and later ordered to drawings and specifications. This step was clearly out of the province of the Society, as it would immediately involve engineering, drafting and experimental expense. When Col. Baker's office was notified of this condition by officials of the Society, his office decided to assume the burden. A request was therefore directed to Secretary of War Baker for an appropriation of $175,000 to be granted to Col. Baker's office to finance the cost of engineering and construction of sample trucks for further consideration. The appropriation was promptly granted and Major (now Brigadier-General) C. B. Drake and Captain Britton were directed to travel to Columbus to notify the industry at its meeting of the new move.

At the meeting General Manager Clarkson gave a history of the work of the military truck and standardization up to that time, after which Mr. Graham asked for the floor and presented the arguments and views of the various truck makers who were opposed to the standardization program. Mr. Younger also spoke in support of these remarks and several other members spoke in defense of the program. Major Drake and Captain Britton were then introduced. The former spoke somewhat briefly, and expressed the appreciation of the office of Quartermaster General for the assistance of the Society. Captain Britton announced the decision of the War Department to carry out the complete design and standardization of Class A and B War Trucks.

War Department Begins Design Work

This really ended the official connection of the S. A. E. as a society with the standardized truck. A number of the engineers who had cooperated in the work up to this date were later asked to go to Washington to assist in this design, the greater part of these engineers being called to Washington to commence work about Aug. 1. It must be remembered that all previous work had been done on such items as attaching brackets, connecting flanges, etc., the object being interchangeability of units only; although a great deal of the work already done was of value to the work which followed, there was a great deal more work to be done than had been done.

The new work in Washington was greatly handicapped at the beginning due to lack of proper quarters, drawing-boards and other facilities. The worst handicap, however, was the lack of competent direction and organization, there being no definite channels of authority or responsibility. So great was this handicap that practically the entire month of August was spent in preliminary lay-outs before several fundamental principles, such as type of axle, bore and stroke of engine, location of clutch and method of spring-shackle lubrication were settled. In order to correct this, a Schedule Committee, with A. W. Copland as chairman, was formed, consisting of the chairmen of the various groups. The nominal object of this committee was to set time schedules for the completion of the work and to make certain the meeting of these schedules. To accomplish their object it was necessary for this committee to assist in making some important decisions, which, as stated above, had not yet been made. From this on, the work went forward rapidly and the Schedule Committee felt able to set Sept. 10, 1917, as the date upon which the design should be completed.

The design of the various parts was practically 90 per cent complete on this date, and the chassis design was finished a few days later. By Oct. 1 all the designs, details and checking were ready. Oct. 10 was set as the date for the completion of the two sample trucks, and one was actually ready three days ahead and the other one day ahead of schedule. The total time elapsed between the calling together of the engineers to begin work and the completion of the first sample truck was sixty-nine days, a very creditable record, and one which has never been equalled in the motor car industry.

The two trucks were driven overland to Washington, one of them being required to cross the Allegheny Mountains in the first snowstorm of the year. They arrived in excellent condition, and the engineers and drivers who accompanied these trucks expressed great satisfaction with their performance. On Oct. 19, the trucks were presented by Col. Baker to Secretary Baker in a formal ceremony at the State, War and Navy Building, and were afterward driven to the White House, where they were examined by President Wilson.

Quantity Production Commenced

The General Staff and Secretary Baker having authorized the procurement and production of 10,000 of these Class B Trucks, under the direction of Col. Baker, it became necessary to proceed rapidly. Several prominent men from the industry were considered, and finally Quartermaster-General Sharpe, at Col. Baker's request, practically commandeered the services of Christian Girl. Mr. Girl little relished the job, fully realizing the criticism he would be subjected to by opponents of standardization, as well as hidden obstacles that would be put in his path. Up to the time his services were "drafted," he had small knowledge of what had transpired, and stood practically in the position of a factory manager who is given a set of prints and directed to "build 10,000 of these whether you like it or not." He was finally persuaded that it was his patriotic duty to acquiesce, and after three days at home to put his private and company affairs in shape, he returned to Washington on Sept. 6, 1917, and organized what was known as the Military Truck Production Section of the Transportation Division of the Quartermaster Corps. The organization which he built up around him consisted of men thoroughly familiar with the various branches of the automobile industry. He attempted to fill each position with a man especially fitted by years of training and experience. This was something theretofore unknown in the War Department, it being an old rule in the army that an officer is supposed to be able to handle any class of work, no matter what his previous experience. Herein Col. Baker raised himself above the traditions of his contemporaries.

The duties of the production organization were to:

(1) Survey all plants of prospective producers for capacity in every respect as regards ability to produce articles of which purchase was to be made
(2) Report the names of parts makers for raw material for priority action through the Automotive Products Section of the War Industries Board
(3) See that parts were produced according to schedule
(4) See that trucks were delivered on schedule time
(5) Inspect all purchases from raw material to finished product; including also the testing of trucks

An organization to handle this work was built up in a very short time, and it can be seen that no small organization could handle such a task.

The Production Department, being composed of civilians, did not make a single purchase, merely presenting data to the Purchasing Board, which was composed as follows:

Chairman, Gen. C. B. Baker; Col. Charles B. Drake, Lieut.-Col. James W. Furlow, Major Edward Orton, Jr., and Capt. L. H. Coart, secretary of the committee.

The work of plant survey, securing of bids, etc., progressed at an unusual rate of speed, and early in November contracts were let, both for parts and for chassis assembly. In all cases it was attempted to have at least three purveyors for each part, while the chassis assembly was divided among seventeen truck builders, the smallest number given to any one maker being 500 and the largest 1000. In spite of unanticipated obstacles, consisting of freight congestion, lack of fuel and opposition to commissioning inspectors to comply with army regulations, production came through in a very satisfactory manner, and five trucks, which were rushed through as a check on the tools were completed about Jan. 10, 1918.

By April, 1918, production was proceeding so satisfactorily that the General Staff authorized the purchase of an additional 8000 of these vehicles. In August, 1918, an additional 25,000 were authorized, and had the armistice not been signed these would have been well in production by this time.

There have been many criticisms since the beginning of the standardized military truck program. Before the truck was designed and production commenced, there were many predictions of failure, it being stated that a truck brought out in so short a time would surely have some fatal errors of design which would probably greatly

delay production. In view of some inherent defects which developed in a few of the stock trucks in the A. E. F., which defects did not develop in the Class B trucks, the demand that the B truck be abandoned early in its history was ill-founded. It was further stated that these trucks could not be produced in time to be of value, and that it would seriously delay the military program if the Quartermaster Corps attempted to carry out this program.

Results have shown these fears and predictions to be groundless. In fact, there has never been a time when production and delivery of Class B trucks at the ports of embarkation have not exceeded the allotted cargo space.

Production Difficulties

After trucks were in production, a number of troubles were, of course, encountered, the majority of them being manufacturing difficulties; some, however, were design faults, and at the time they were discovered, loomed up very large. However, the Engineering Department, which had by that time been built up into a permanent organization with a more complete testing and experimental department than any truck manufacturer in the country can boast of, attacked these problems with determination, and, with the efficient aid of the manufacturers involved, was able to overcome every difficulty that arose. It is unfortunate that a larger number of these trucks were not shipped to France and put into active service. It was evident that influence was exerted in the A. E. F. to prevent B trucks from being ordered overseas; just why it cannot be stated, for, if the truck were a failure, service in the A. E. F. would soon have condemned it. I found evidence in France, when I arrived at general headquarters there in May, 1918, that propaganda had been spread to the effect that the B truck was a failure, and they did not want them in France. Everyone who has had experience with the Class B trucks, either in this country or on the other side, agrees that it is the greatest thing of its kind ever produced. I have accompanied several convoys of these trucks across the Allegheny Mountains, have seen them in operation in France, have interviewed numerous convoy officers, have letters from officers of the American Expeditionary Forces in charge of these trucks, and am firmly convinced by the great bulk of this testimony that the Class B truck is an unqualified success.

The various details of construction have been described in papers read before the Society, by men who had an active part in this work, so that it is not considered necessary to give a repetition of that information in this paper. There is one feature of this design, however, which I consider worthy of mention at this time, as it is bound to have a marked effect on future commercial vehicle design, and that is, the truck's unusual amount of low-gear ability. The military truck specifications laid great stress on this point and went so far as to define it by means of a so-called "tractive factor." Later experience has proved that the figure specified for high-gear ability was somewhat in excess of the proper amount for good economy, as well as satisfactory performance.

The low-gear ability specified, however, has justified itself to such an extent that there is today a decided trend among truck engineers in this direction. Four-speed transmissions, with a very low-gear ratio giving all the tractive effort that the adhesion of the tires will permit, will undoubtedly be incorporated in the design of a great majority of high-grade trucks within the coming year. This consideration, coupled with the possible advent of "locking-type" differentials, makes necessary axle drive-shafts of sufficient size to slip the wheels.

It is very unfortunate that the Class A and Class AA trucks were not put into production, since these would have given the Government a consistent line of trucks capable of taking care of practically all the needs of the army motor transport, with all of the advantages that standardization gives.

Trucks in Service in France

Experience of the American Motor Transport in France has demonstrated beyond question the value of standardization. Due partly to lack of shipping space, causing the necessity for purchases of motor equipment in Europe, as well as to the numerous motor transport programs of the various departments of the army, there were 214 makes of motor vehicles used by the American troops in France. You may be able to imagine the confusion in the maintenance department and the number of spare parts which had to be carried in order to attempt anything like proper upkeep and operation of these vehicles. The fact is, that it was impossible to carry sufficient parts to maintain a large number of these miscellaneous types, and when a part failed, it was necessary to either junk the vehicle or rob another one already out of commission for some other cause. Here began the outstanding evil in army motor maintenance, which remains; the need of tens of thousands of different kinds of spare parts and accessories for up-keep. The Motor Transport Corps of the A. E. F. was required to keep 57,000 non-interchangeable parts in stock, besides 13,000 kinds of bolts, nuts and screws—a total of 70,000 separate items. Our general "unpreparedness for war" may be blamed for some of the difficulty, but the lesson has been sad and expensive, and it is hoped it will not be repeated should we ever be so unfortunate as to have another war.

The absurdity of attempting to maintain and operate such a heterogeneous collection of vehicles is apparent to every one, when you consider that the army motor transport could have been handled by a total of fourteen types. The following list needs no argument to support it:

(1) Light five-passenger car
(2) Heavy seven-passenger car
(3) ¾ to 1 ton truck
(4) 1½ to 2 ton truck
(5) 3 to 5 ton truck
(6) Cargo caterpillar or four-wheel-drive type of truck
(7) Motorcycle
(8) ¾-ton trailer, cart type
(9) 1½-ton trailer, cart type
(10) 1½-ton trailer, four-wheel type
(11) 3 to 4 ton trailer, four-wheel type
(12) 6 to 7 ton trailer, four-wheel type
(13) 10-ton trailer, four-wheel type
(14) Bicycle

Cooperation Between Society and Army

The value of the cooperation which the Society has given the army has been proved in every step of the "game." The military truck specifications are admitted to be the best thing of their kind ever produced, the Class B truck is a proved success, and this in itself demonstrates how successful the whole standardization pro-

gram would have been had it been carried out. Practically all automotive engineers who have been serving the Government during the war either have or will shortly sever their connections to resume their peace-time occupations. In fact, with the present limitations on salary of army officers and other Government employes, it would be impossible for the Motor Transport Corps to induce many engineers of standing to remain in its employ. This means that there must be even greater cooperation in the future between the Society and the Motor Transport Corps, than there has been in the past.

We have profited greatly by our experience in this line, and it can safely be predicted that the results of future cooperation will be of even greater value than those of the past. It has been demonstrated that standard trucks, like standard escort wagons, can be ordered and delivered quickly in quantities when emergency arises, and any truck builder can build the trucks, just as any wagon builder can build the wagons, when once their value and ultimate economy are appreciated.

THE POWER RATING OF INTERNAL-COMBUSTION ENGINES

THE question of the power rating of internal-combustion engines is one to which much less attention has been given than is merited by the importance of the subject. The rating of any engine depends in measure upon the characteristics of its manufacturer. A cautious and conservative manufacturer will list an engine with a fair margin of power either to prevent undue disputation under circumstances that may arise after installation, to provide for inaccuracies in measurement of power on the site, or to give conditions of maximum reliability in service, and so to promote good-will and to foster a relationship conducive to obtaining repeat orders and increase of business.

To rate an engine at too high a power will lead almost inevitably to numerous troubles, unless the duty demanded be less than the rating, which circumstance will only occasionally occur. On the other hand, an internal-combustion engine should not be rated at so low a figure that its average performance will be at considerably less than maximum efficiency. There is little temptation to adopt this latter course since not only would the engine be constrained to operate normally at considerably less than maximum efficiency, but its size and weight would preclude it from coming within desirable competitive limits in price.

With internal-combustion engines the curve of power and efficiency is fairly flat between quite wide limits, and this gives the manufacturer a certain range over which to list the power output of his engines. A further consideration, especially where, for commercial reasons, a wide margin of power cannot be adopted, is the type of duty demanded of the engine.

The maximum power that it is safe to develop continuously with an internal-combustion engine is determined in many types, such as the Diesel engine, by the cylinder which is developing the most power. Thus in a four-cylinder engine, suppose, as may well be the case, the cylinders are developing powers in the ratio of 0.8, 0.9, 1.0 and 1.1, the engine is developing altogether a power represented by 3.8, and one of the cylinders is developing 10 per cent overload. If, with careful tuning, the powers were 1, 1, 1 and 1, the engine would give out power represented by 4 without any cylinders being overloaded. If it is possible under ordinary working conditions to get conditions of power per cylinder represented by 0.8, 0.9, 1.0 and 1.1, it would be preferable to rate the engine at 0.7, 0.8, 0.9 and 1.0, or 3.4 total power, although it may develop on test with absolutely satisfactory results power equivalent to 4, or some 17 per cent above the rated power.

The foregoing conditions operate only where the quantity of air or mixture drawn into the cylinder does not constitute the limiting factor, as is sometimes the case, as, for instance, with gasoline engines, where the designed diameter and lift of the inlet valves are restricted to this end. Early difficulties of rating with gasoline engines for motor cars led the authorities to adopt for rating and taxation a formula depending on cylinder diameter and number of cylinders, disregarding speed of revolution or length of stroke. Such a course led inevitably to increased stroke-bore ratios, high speeds of revolution and high volumetric efficiency.

Difficulties of Rating

The chief difficulty on the subject of rating of engines has been in connection with the making of comparisons of weights, sizes, prices of various engines, etc. To compare engines of two different makes having the same number of cylinders, same stroke and speed of revolution, one will have a cylinder diameter, say, of 10 in. and the other of 11 in. Is this difference in size due to a more cautious policy toward higher reliability in the case of the maker of the 11-in. diameter cylinder, or to higher efficiency and better design in the case of the 10-in. diameter cylinder? A very careful specification and complete trials will probably go far to supply an answer to this question, yet the factor of tuning up and the latent liability of the two engines to get out of tune under working conditions can be proved only under actual working conditions. Other factors being equal, the engine with the cylinder of lesser diameter will be the smaller, lighter and cheaper.

Recently an elaborate comparison of two-and four-cycle Diesel engines was made in which the two-cycle was credited with the maximum performances attained on the test bed, as against the results achieved under normal full-load running conditions at sea, in the case of the four-cycle engine. Moreover, the power loading of the four-cycle examples chosen was conservative and allowed a very considerable margin for contingencies. With internal-combustion prime movers, and especially for marine work where full power is almost continuously called for, a small increase in speed of revolution of the propeller is accompanied by a disproportionately large increase in power, and where conditions of supervision of running, adjustment and overhaul at sea are less favorable than on land, a certain substantial margin of power is most desirable.

While experience has clearly shown the consequences of the errors of the past in rating engines at too high a figure, it would be most detrimental to progress in design to impose any limit on ingenuity and to restrict in the slightest way the just rewards of increased efficiency and improved performance by attempting to formulate a standard of rating for any of the main types of engines now built; yet it were better for manufacturers to cut the price of the engine to the finest limits rather than the dimensions, and for buyers to insist on such tests as would clearly prove the ability of the engine to stand up to its work. The rating and the normal load should be less than can be maintained continuously on the test bench, by a certain percentage depending on the type of duty required, and the largest percentage should be allowed for such duty as is called for from marine engines. —*Engineering* (London).

The British Civil Aerial Transport Committee Report

A CIVIL aerial transport committee appointed in Great Britain has made a report which is comprehensive and has been published in as complete form as was permissible in view of the confidential and secret information on which the recommendations of the committee and its special sub-committees were based. The committee was established in 1917 to consider, from domestic, imperial and international points of view, the steps which should be taken to develop and regulate post-war aviation for civil and commercial purposes.

One portion of the report relates to municipal control and legislation, another to business questions concerning the position of the aircraft manufacturing industry, and others analyze labor questions and problems of scientific research, and the education of designers, engineers and pilots. The report is indicative of the wonderfully thorough and effective manner in which the British handle aeronautic matters. The development and production work which the British scientists and engineers did in aircraft during the war was remarkable, the scope of their proceedings being wide and their engineering and laboratory organizations very extensive and prolific.

The sections of the report in which S. A. E. members will be most interested cover technical and practical questions as to the possibilities of performance of aircraft, and as to the requirements of aerial service. The observations and recommendations of the committee in this connection are summarized below:

The carriage of mail, passengers and certain classes of goods by aircraft will present no difficulty from the technical point of view. We are confident that demands for aerial service to provide such carriage will arise immediately at the conclusion of the war, and that it is imperative every endeavor should be made to prepare for these. It is scarcely necessary to point out the extreme importance to this country (England) of being first in the field in the matter of aerial transport. An experimental service should be organized as early as possible, but this recommendation should not be understood as implying that all other aerial services which may be suggested should await the final results of the experiment. On the contrary, we think that special measures should be taken either by direct state effort or by the encouragement of individual enterprise, with the object of commencing schemes of transport at as early a date as possible.

Owing to the absence of any reliable data to serve as a guide, it has been impossible to frame an estimate of the running costs of aerial services under peace conditions, and consequently of the volume of aerial traffic likely to be forthcoming. We recognize that no good purpose would be served by putting forward estimated figures of running costs which, from the nature of the case, would necessarily be almost wholly the result of guesswork. Nevertheless, it seems worth while to draw attention to certain considerations affecting the matter, if only with a view to pointing out the factors which must limit the cost of aerial services if they are to hold their own in competition with alternative means of transport, and which are likely to limit the demand for them.

It is necessary to distinguish with reference to surface transport between developed and undeveloped countries. In developed countries the governing advantage of aerial over surface transport must be speed. The extent of the advantage will vary with the effectiveness of the alternative means, but where such means exist it must be assumed that they will be improved and rendered fully effective. In undeveloped countries the advantage will lie with the means of transport best calculated to provide access to points previously inaccessible, and the lack of road or railway communication must add vastly to the commercial importance of the ubiquitous flightways of the air. In the case of countries in or between which surface transport facilities are interrupted, as, for example, where there is the interruption of a sea passage, both the factors above mentioned should operate to the advantage of aerial transport. In the paragraphs which follow we have regard chiefly to developed countries where aerial transport is called on to eclipse the speed of surface transport.

Speed the Chief Factor

High load and speed are antagonistic elements in the problem. To secure high speed, the commercial load must be kept within narrow limits. From the figures submitted to us it would appear not to exceed 25 per cent of the total loaded weight of an airplane. That is to say, the loading efficiency or the ratio of useful load to gross weight in an airplane is only poor. On this account it would seem as though airplane transport must always remain auxiliary to surface transport, and that speed must always be in the end the predominant factor of advantage.

Comparing the train with the airplane, the former as a traffic unit of movement is large. There must, therefore, be wider intervals of delay for the accumulation of loads between successive units than in the case of the airplane. This is a small unit, and therefore a flow of urgent traffic can be given by a constant succession of units from the airdrome, with consequent time economy. The airplane affords the better time-saving the longer the journeys, because in long journeys the time lost between the home and the airdrome is a less appreciable factor; only the saving of time from speedy flight counteracts this loss for journeys in excess of some minimum distance.

The absence of a track is a great financial advantage. The expenses standing in lieu thereof are far less, viz., the cost of landing grounds, wireless installations, weather-reporting services and signalling of routes at night or in fog. The cost of landing grounds will only be a small factor per "airplane mile" in any reasonable commercial scheme of transport, but even as airplanes become increasingly reliable the need for alighting grounds will not be wholly removed, since safety is a paramount condition; moreover, multiple-engined machines, desirable as they are from the point of view of safety, are commercially justified only when the loads are great enough to warrant aircraft of this size.

Prospective Passenger Traffic

In canvassing the traffic expectations of the immediate future a distinction may be drawn between passenger and freight traffic. Passenger traffic divides itself into two distinct sections, that which moves for business and that which moves for pleasure. Business traffic will turn primarily on speed and reliability, and will consist of inward and outward traffic where rapidity of movement is an important consideration. Economy of time is of great importance to many business men who find absence from their regular place of work disadvantageous. As it becomes possible to fly 400 to 500 miles out and home by airplane within the day, and to give a reasonable interval for the conduct of business between the flights, so it becomes likely that many business men will avail themselves of the opportunity.

The occasional use of single machines for rapid journeys in any direction rather than along a fixed route, carrying

occupants who pay special fees for the high speed, will probably be one of the early and increasing lines of development. It will educate the public and prepare it for regular service. This could be undertaken immediately peace comes, and would not be open to the same objection as premature attempt to run a daily service to scheduled time.

With regard to passenger traffic generally, the question of safety in connection, more particularly, with airplanes will be of the highest importance. The large number of accidents which occur at the present time are, in our opinion, chiefly due to inexperience and risks taken during training and practice which would not be justified in ordinary times. This subject is no doubt constantly before the authorities in the experimental departments connected with aeronautics, and investigations are, it is understood, being made into the cause of accidents by the Accident Investigation Department of the Air Ministry. Improvements are continually being made with the object of reducing accidents, and in the ordinary course of events it is not too much to expect a large reduction in their number at the conclusion of the war. Thus the chief deterrent to universal flying will be removed without any remarkable invention being made.

Pleasure traffic will depend on novelty, comfort and safety. Flight may afford pleasure in itself, but pleasure traffic will be seasonal in character, will depend largely on weather, and will be more costly the more irregular it is. It is likely that the small regular demand will increase as flight movement becomes a habit. The demand in the immediate future will probably not be extensive, owing to the cost, but it would appear practicable to open routes from well-chosen centers.

Airplane Freight and Mail Service

Freight traffic will be for mails and general freight. Commercial considerations are not the only ones to be taken into account in determining upon an aerial mail. It is not indispensable that the cost of a letter by aerial mail should be fully borne by the service, if imperial or other reasons demand that the use of aircraft shall thus be developed. Mails offer a most promising class of traffic, because the load to be carried is reasonably uniform, the weight small and the demand for speed great. The prospect of an aerial mail will be best where the conditions operating to the advantage of aerial transport make themselves most markedly felt.

It has been shown that in the case of services between London and large provincial towns a flight of at least 3 hr., at the average rate of 100 miles per hr., would be required for the speed of an air mail service to reveal itself, and to offer a sufficiently marked saving in time over land transit; on an oversea journey, such as the passage to Dublin, the saving of time is much more evident. It would appear necessary to charge some such fee as 1s. or more per letter for an inland air mail to prove remunerative.

The cost of cable communication to Johannesburg, for example, at £8 10s. per 100 words, a message taking about 24 hr. to reach its destination, can be contrasted with a charge of 2s. 6d., of sending a letter of 5000 words to the same spot in 6 days by airplane. The London mail could in the future be conveyed to Calcutta in 4 days, as against 16 days, the minimum at present. These instances illustrate the intrinsic utility of air services, apart from the value of making closer links within the Empire and of giving support to the construction of aircraft so as to be ready for war emergencies.

It is more difficult to settle the reasonable expectation of general freight traffic, which must take the form of express parcels, usually of small weight. Furs, lace, jewels, precious metals, extracts, essences, valuable feathers, etc., might be carried by air because of their high value; also rare and out of season fruits and vegetables, flowers and perishable articles generally. Newspapers and periodicals afford scope for aerial services, because news grows stale quickly. Drugs, dyes, chemicals, medicines, optical, surgical and other instruments will be so carried, as often these are wanted quickly. Wherever, for want of some article, life is endangered or industry is at a standstill, as where some spare part or tool is required for a machine, the airplane will afford the quick remedy, and its flight will be profitable. Cinematograph films, gramophone records and commercial samples may figure in the class of goods carried by aircraft. Their rapid distribution will quicken exchange, and this will react to increase the volume of traffic, but the whole series of illustrations above given tends only to show how limited the total volume or weight of aerial goods traffic is likely to be in developed countries.

Airship and Airplane Compared

As to the respective capacities of the airship and the airplane, we think it advisable to make some general comparison, from the commercial point of view. For this purpose the largest type of airship is taken as an example, since it is found that as the size of an airship increases the ratio of its useful load to gross weight improves, *e.g.*, for a ship of 60 tons gross, 30 tons of disposable load is available. This represents roughly nine times the load carrying capacity of the largest modern airplane. The prime cost per pound of disposable load in the case of an airship is estimated at almost one-half the prime cost per pound in the case of an airplane. The economic limit of a journey without landing is about 1000 miles in the case of an airship, as against 500 miles in the case of an airplane. The airship, therefore, has the advantage of a greater load capacity; but its speed, under present conditions, is slower, being probably not more than 60 miles per hr. In this respect the performance of the airship on overland routes would appear in general to be open to keener competition from rail transport. On the other hand, on sea routes the airship will, save in contrary winds, have a marked advantage over steamships as to speed. As compared with the airplane, the cost of handling and housing airships will be higher, and, until open-air mooring is fully developed, the regularity of airship service will be more adversely affected by high winds than that of airplane service. On journeys in which speed is not the most material factor, and particularly where passengers are being carried and safety is consequently a paramount consideration, the airship offers advantages over the airplane in the way of comfort, ease of navigation, capacity for safe flight at low altitudes and high ratio of disposable load.

On the question of landing grounds along aerial routes there is some divergence of opinion. While we agree in not feeling able to recommend that chains of landing grounds should necessarily be laid out at regular and comparatively short—say 10-mile—intervals along aerial routes, especially in developed countries, we consider, nevertheless, that the advantages of lines of landing grounds on certain main routes would be very great, and that such lines would largely assist the development of civil aerial transport. In undeveloped countries the consequent expense will be less material in view of the comparative advantages which aircraft will enjoy in competition with other forms of transport. Regular sea stations for the landing of aircraft are at the outset essential if transoceanic aerial transport is to be seriously attempted. It is recommended that when questions of laying out, maintaining or abandoning landing grounds for military purposes have to be considered, regard should be had, if possible, to the probable needs of civil aerial transport hereafter. The establishment of landing grounds within urban areas should not necessarily be precluded, and the institution of rapid transit schemes between airdromes and town centers, such as post offices, would be of great value. Developments in airplane design may in the future permit of landing safely and conveniently within a narrow compass; and, as has already been indicated, a central situation for an airdrome for civil aerial traffic has considerable importance.

We are of opinion that it will not be necessary for the state to lay down any definite scheme for the provision of route marks. Probable improvements of signalling by directional wireless and of other methods from airdromes by night and day would seem to make it inadvisable to embark upon the organization of any universal system of arbitrary markings.

We desire to draw attention to the great importance of meteorology in connection with aerial routes and services generally. A system of meteorological stations should be organized immediately.

The total volume of aerial freight traffic to be anticipated will be very limited, and even on the most hopeful view of the probable extent of the demand for aerial carriage of mails and passengers, the number of aircraft required to meet it will be small in comparison with the vast number produced for the purposes of war.

Future of the Industry

The aircraft producing industry in this country has developed during the war in a phenomenal manner, owing solely to the unexampled demands of the naval and military authorities, and has grown to considerable proportions in Canada also, where before the war it did not exist.

This great industrial organization, amply equipped as it is with capital, material, machinery, expert knowledge and trained labor, is in anything but a secure position. Fostered as it has been wholly by the exceptional conditions of the last 4 yr., it must wither, and very rapidly, in proportion as these conditions or their equivalents cease to exist.

The development of civil aerial transport services to create a market for the manufacturing industry and consequently to enable it to maintain its power of production and of progressive improvement in design is essential for the safety of the Empire. Aerial transport services cannot be developed by the ordinary commercial methods so as to secure the required result, and state action of some kind in developing aerial transport services is therefore unavoidable.

It requires but little imagination to visualize the possibilities of aerial communication in such a country as Canada, where the journey from Halifax to Victoria is one of nearly 3000 miles, passing through such centers as Quebec, Montreal, Ottawa, Toronto, Winnipeg, Calgary and Vancouver; or in Australia, where a journey around the coast from Brisbane to Perth, through Sydney, Melbourne and Adelaide is slightly longer; or in the Union of South Africa, where a journey from Capetown to Johannesburg is one of 800 miles, and leads on to Buluwayo or Salisbury, and thence across Northern Rhodesia and what was once German East Africa, to British East Africa, the Nile Valley and Cairo.

It is an indispensable preliminary to proper scientific research in aerodynamics that there should be a complete and reliable treatise on the subject kept constantly up to date as the science progresses, thus containing in convenient form the whole body of knowledge available at any given time.

A distinction may legitimately be drawn between privately owned aircraft and aircraft carrying passengers for hire. We think, nevertheless, that the appropriate Government Department should have power to order an official investigation to be held, if it is thought necessary in the public interest, in any case of serious accident, no matter what class of aircraft may be involved in such accident. Inquiries might, at the discretion of the appropriate Government Department, be conducted through the agency of an unofficial body, such as the Public Safety and Accidents Investigation Committee of the Royal Aero Club and Aeronautical Society. It appears to us that the knowledge that a state authority was empowered to hold an investigation into any case of serious accident, if it thought fit, would give the public a sense of security, and would thus be to the advantage of the aerial transport industry rather than otherwise. It does not seem necessary to apprehend that a government authority would hamper the industry by directing unnecessary inquiries into a number of trifling accidents arising from easily ascertainable causes.

BRITISH CYCLECAR DEVELOPMENT

THERE will be four classes interested in cyclecars: (1) Legitimate pre-war cyclecar users; (2) motor-cyclists, who for many reasons may desire something better; (3) light car men, who for obvious reasons are going in for something cheaper, and (4) the general public, not yet familiar with the advantages and economies of a cyclecar, but certain to become interested. The question which must govern the future lines of cyclecar development resolves itself into whether the manufacturer is going to turn out four slightly different models to cater for the four classes of probable patrons or endeavor to produce a vehicle which will suit all. Undoubtedly there will be more three-wheelers in the future. The difference between three guineas and one is worth considering when this expense comes on top of buying and equipping the car, apart from other claims.

There will be a tendency among cyclecar owners to favor a water-cooled engine of the maximum displacement in the range of the cyclecar limit; despite this, it would seem that the air-cooled model will continue to be the favorite, although it may be modified slightly by the addition of a fan and cowls to insure that a draft of air is induced round the cylinders. Overhead valves will not be as unpopular as they were in the old days when breakages were not unknown. Modern metallurgy, combined with improved design, makes the overhead valve possible now and, incidentally, modern metallurgy will mean a lighter engine by reason of the fact that suitable metals will be used to withstand the different strains.

The underside of the crankcase may be ribbed to assist cooling; in fact, everything should be done toward this end. The danger of overheating is a very pressing one when the driver has not the mechanical knowledge and skill to maintain a cool engine. Various parts of the engine must be accessible and adjustable; this applies especially to valve tappets and the magneto. The latter may be driven by a train of wheels as in common motorcycle practice, or by a chain. The latter method is advantageous, inasmuch as the sprocket can be mounted on a taper shaft and pulled up with a nut, thus allowing infinitesimal adjustments to be made. This, undoubtedly, is a good system, but it gives dissatisfaction sooner or later owing to the fact that the threads of the shaft end are stripped, and it becomes impossible to retain the sprocket rigidly in position without dismantling the engine and cutting a new thread of smaller diameter on the magneto driving-shaft. The remedy is very simple, and merely resolves itself into a larger tapered extension and a much larger nut and thread.

During the war a good deal of light was thrown on the loss of efficiency due to condensation. Owing to the fact that heavy fuels have replaced pre-war gasoline, a thorough knowledge of their treatment has become necessary. Inlet pipes, however short, should be jacketed and the air supply drawn from a muff arranged on the exhaust. A split-bearing in the big-end looks like a luxury, a rather expensive addition, when the purpose of the manufacturer is to keep prices down. It is, however, economical in the long run from the owner-driver's point of view, since, if he possesses any workshop knowledge whatever, he should be capable of taking up wear and thus save himself the cost of rebushing. For the same reason split crankshaft bearings should be introduced, regardless of the initial cost.

Regarding the transmission, the majority of manufacturers will fall back on the orthodox gearbox, giving three forward speeds, but not necessarily a reverse. The engine power will be transmitted through a simple type of clutch, preferably a floating plate between two Ferodo grips, and there will be a solid drive to a differentialless back axle by bevel wheels. Alternately, the final drive will be by belts, a countershaft being fitted in the gearbox to attain this end.

One does not expect anything surprising in the way of springs. The conventional quarter-elliptic or semi-elliptic springs have given satisfaction up to the present, but the car might well be underslung to reduce the height and consequently the wind resistance.

The opinions of manufacturers will differ widely in respect to steering. The genuine cyclecar user does not favor the conventional steering to be found on a light car, but, for many reasons, it must be accepted as the best. On the other hand, wire and bobbin steering looks primitive, and it certainly is not motor-cycling practice. Properly adjusted wire and bobbin steering, however, is very hard to beat. It is simplicity itself, does not contain anything that can be said to be complicated, and can be looked after by the veriest tyro. A glance suffices to show whether it is in working order, and all that it requires is the application of thick grease occasionally. Frayed or broken wires are the exception and not the rule, though in this connection it may be said that the whole success of this system depends on the care and forethought with which it is erected in the first place. Direct steering is not favored by all engineers, and it seems improbable that the centrally-pivoted front axle will become very popular.

For frame construction there are several systems to choose from, such as the plain ash frame, the tubular frame, the body made up of planks to act in the capacity of a frame as well, and the airplane fuselage type. At present, however, it seems more than probable that manufacturers will keep to the wooden frame and in some few cases the tubular type.

The body, again, gives the designer a choice of systems. Sheet metal, however, suitably braced by diminutive angle iron will probably be the favorite, and the seating accommodation in very few cases will allow for more than two people.

A hood and screen are a necessity if the general public is to be attracted, the torpedo-like, unprotected body appealing only to the sporting few. Control levers certainly ought to be inside the car, but many manufacturers will cling to the old arrangement.

A review of the developments of the cyclecar does not lead to the belief that there will be many very striking departures; rather, there will be an endeavor to improve what has already been experimented upon, so that the manufacturer can point to his production with confidence and not misgiving. He must remember, however, that the cyclecar is going to appeal to thousands upon thousands of people who previous to the war either had something better or were not in a position to own even such a small car. Finally, appearances and also comfort must be studied. The cyclecar of the future must deprive the caustic critic of any grounds for witticisms on its appearance.—Forecast by contributor in *Light Car and Cyclecar* (London).

How the Army Is Paid

THE Finance Division of the Quartermaster Corps has issued a statement as to the method of procedure used in paying the officers and men of the Army. It is a complete answer to the many loose charges made against the Army pay system and shows that many officers of the Finance Division have cheerfully accepted the responsibility of paying enlisted men who were in need, although legally they had no occasion to do this. The illustration given of the way our troops threw away "everything that did not contribute directly to the task before them" shows why personal records were lost in the heat of battle that doubtless caused much of the subsequent trouble over the pay accounts of the men.

A Yearly Payroll of Over $3,000,000,000

Since April 6, 1917, there has been paid to the officers and enlisted men of the Army $1,577,331,669.70. To this should be added $116,782,994.81 paid in family allowances by the Treasury Department, making a total of $1,694,114,664.51 paid to officers and soldiers and to soldiers' families up to Jan. 3, 1919. It is estimated that it will require $1,257,941,001.52 to pay officers and soldiers for the balance of the fiscal year ending June 30, 1919, and if the Dent bill providing an extra month's pay for discharged officers and men becomes a law there will be added $153,000,000 to the grand total, making the sum of $3,105,055,666.03 paid out to officers, soldiers and soldiers' families since April 6, 1917, without taking into account the amount for family allowances which will be paid to enlisted men's dependents between now and June 30, 1919.

This money has for the most part been paid in cash to individuals, and has been disbursed in the United States, France, England, Italy, Porto Rico, the Canal Zone, Alaska, Hawaii, the Philippine Islands, China, Siberia, Archangel and at the capital of every country in the world except enemy countries, and we may soon be paying troops there.

In the Spanish-American War troops were paid every two months, while in the present war payments have been made monthly to forces scattered around the world. In this country the cantonments, with inexperienced officers and men, made a somewhat trying pay problem that was soon solved, however, and in the past year the big camps and cantonments have been paid in full as an average on the fifth of the month. In several of the cantonments, some of them containing from 40,000 to 60,000 men, payments have been completed on the last day of the month in which the pay accrued, and in many others full settlement has been made on the first day of the succeeding month.

From Dec. 1 to 21, 1918, 500,000 enlisted men were discharged from the Army and were paid in full without delay. This operation comprehended such factors as clothing money due, longevity pay, foreign service pay, allotments to the Bureau of War Risk Insurance and allotments through the War Department system, all of which must be prorated, travel allowances, charges against the soldier for lost property, and many other matters requiring consideration under law and regulations. The final payroll of a soldier, because of the requirements of law, Treasury Department decisions and regulations, is an intricate financial problem.

Complications of Overseas Problem

The payment of troops overseas presented entirely new difficulties, the restrictions of law and regulations being complicated further by war conditions that relegated the matter of pay to the rear. It was impossible to pay troops in action, and the troops were not thinking of pay. When American troops arrived overseas they were hurried to the front and their baggage containing their records followed them when transportation was available. Then began rapid movements and consequently frequent separation at every point. In some cases organization commanders and their commands had records and baggage. In one or two cases trains proceeding toward the front were destroyed by aerial bombs, causing the loss of baggage and records of troops. To meet this condition an attempt was made to provide enlisted men with pay cards and pay books, so that if wounded or separated from their commands they would be able to establish their identity and secure their pay. The pay cards were available in July and the pay books were issued in November, but few of the casuals, wounded or sick, who have heretofore arrived from overseas, have either pay cards or pay books. In some cases without doubt the soldier when going into actual conflict stripped himself of everything that did not contribute directly to the task before him, as is the American soldier's custom, and left his papers with the rest of his abandoned equipment.

Another phase of the situation that affected many of the casuals who have arrived in this country without records of any kind was the brigading of American troops with Belgian, French, British and Italian organizations. Many hundreds of thousands of troops were moved between darkness and dawn, when it was necessary to have a concentration of men at a given point, and in the teeth of a furious attack records were forgotten. When a man was wounded he was evacuated through Belgian, British, French or Italian hospitals, and from there to the seaboard, and then, as soon as he could be moved, to a transport and back home, while his records might be up near the front line under control of officers and men who were marching all night and fighting all day. In the Argonne Forest one shell killed a non-commissioned officer and wounded thirty men belonging to a field artillery regiment. In the fighting at this point one battalion of this regiment lost five officers in one day's fighting. The wounded were immediately sent through the various hospitals and many to the port of debarkation and on to the United States without at any time coming within hailing distance of the records of the regiment, which in this case were well up to the front. In the rapid advance made the regiment was ignorant of what had happened to those who were wounded. They knew that they were wounded or had disappeared from the line.

Orders were issued overseas that no wounded or sick soldier should be allowed to go aboard a transport for transportation back to the States unless he was provided with all his papers, so that he could be paid on his arrival here, and if it was found necessary to discharge him, that he could be given his final pay in full, including his travel allowance. It was evidently found impossible to hold these casuals for an indefinite time at the port of embarkation in France when the men themselves were eager to reach home, and military policy dictated that they should be returned to the United States as soon as possible. Few soldiers arrive here who have not been given partial pay before leaving France. Immediately on their arrival in this country they are given a partial payment on the soldier's own statement as to the status of his account. Most soldiers have insurance premiums due and allotments on the Treasury Department that support family allowances, and in making partial payments without supporting papers great risk is necessarily run, but the finance officers are making these payments all over the country and cheerfully shouldering the financial risk and accountability so that the men from over there, who have faced the discomforts of the trenches and the perils of the front, shall have some money for their use.

How Returning Men Are Financed

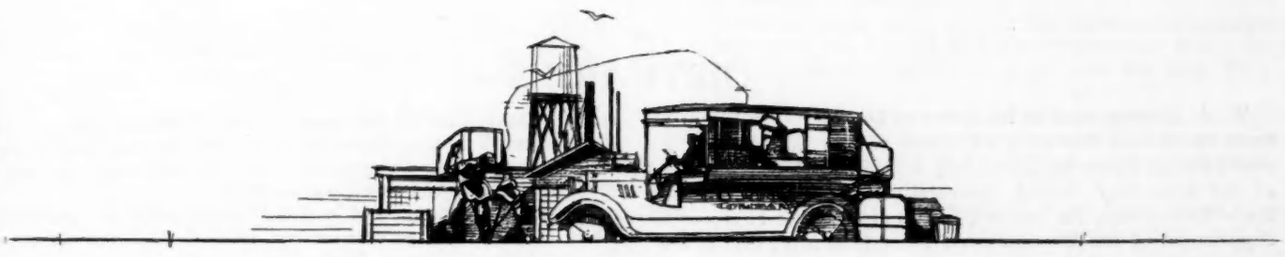
At Walter Reed Hospital, Washington, for some months past the casuals, nearly 400 in number, have been paid on rolls certified to by the Director of Finance, the only supporting papers being the affidavits of the soldiers. The finance officers who pay these casuals correspond to the cashier of a bank. They have no control of the soldier's papers and are not responsible for their execution and care. The soldier without papers corresponds to the applicant for

funds at the cashier's window. He has no checkbook, no evidence of deposit and no identification papers. Under these conditions the cashier refuses the applicant. The finance officer, however, does not refuse the soldier, but accepts his statement and makes him an advance on account, and the finance officer has no protection under the law for payments made under these conditions.

In the case of soldiers discharged, who are without papers, a graver situation is confronted. The final payment marks the actual separation of the men from the service, and for an overpayment there is no recourse. The soldier has due him accrued pay for perhaps several prior months, less partial payments made during those months. He is entitled to 3½ cents per mile to the place of his induction into the service, he has possibly deposits and interest due him, while from this total must be deducted his insurance premium, the pro rata share of his allotment on the Treasury Department to support his family allowance, the settlement of his allotment through the War Department for his Liberty Bond subscription or for other purposes, while there are other allowances and possibly other charges which enter into his complicated account. The officer who certifies to the correctness of such an account, trusting to the accuracy of the soldier's memory and his honesty, and the finance officer who pays many such accounts, face early bankruptcy. The urgency of the case, however, dictated decisive action and instructions were issued by the Director of Finance, with the approval of the Chief of Staff, to commanding officers of all hospitals to prepare final statements from the unsupported affidavit of the soldier, and finance officers are making settlement of such final papers all over the country.

There is no authority in law for either the partial payments or these final payments on the statement of the enlisted men, and Congress has been asked by the Secretary of War to sanction this procdure by necessary legislation. Many of the casuals now arriving are provided with pay books which contain in some cases enough of the soldier's military history to enable payment to be made. Whenever a report is received in Washington that casuals have arrived at a hospital who have pay due them for any prior period, a finance officer is immediately ordered there to make a settlement of the account. At each of the ports of debarkation in this country finance officers with a sufficient force await the arrival of casuals to pay them something on account. Occasionally the condition of patients is such that payment cannot be made, but in the majority of cases payment is made, and no casual or other enlisted men from overseas who has a legitimate claim for pay need go without funds.

Finance officers are available at every port of debarkation, at every cantonment, camp and headquarters and at every hospital, and the instructions issued are explicit and comprehensive that if a soldier has no papers he is to be given a partial payment on his own statement and final payment on his affidavit. In some of the earlier cases men without papers were given their travel allowances on their discharge so that they might reach their homes and were given instructions as to how to proceed to secure what balance of pay was due them. In other cases commanding officers of hospitals have hesitated to certify a soldier's final statement without supporting papers, but it is thought these cases are rare. In all cases, so far as the record shows, all discharged men are given their travel allowances, which, with the reduction in railroad fares secured by the War Department, insures a comfortable journey to their homes, while in most cases discharged men receive every penny which they claim is due them.—*Army and Navy Journal.*



Activities of S. A. E. Sections

A JOINT meeting of the Metropolitan Section and the New York Section of the American Society of Mechanical Engineers will be held at the Automobile Club of America, New York City, April 9. The subject of heavy fuel engines will be discussed from the standpoints of their scope, limitations and applications. The papers to be presented will include one by C. Naramore, U. S. Bureau of Mines, dealing with the adaptation of fuel to the engine, with an analysis of the different natural and manufactured fuels, and another by Prof. Herman Diederichs, Cornell University, on the Adaptation of the Engine to the Fuel. Other topics to be discussed will include the economics of the situation with relation to the different grades of fuel and their relative cost; variations in engine cost, complexity, weight, efficiency, maintenance and operating care, and applications where skilled operators are and are not available. The various phases of the different types of heavy fuel engines such as limitations as to horsepower per cylinder, weight per horsepower, fuel consumption, relative advantages of the two and four cycle designs, relative cost, range of fuel which can be used and ease of starting and kinds of starters required will also be discussed. A paper on Carbureter Type Engines for Heavy Fuels as Applied to Vehicles and Other Uses will be presented by J. H. Hunt, experimental engineer, Dayton Engineering Laboratories Co. Papers dealing with the use of engines with hot bulb and other forms of hot metal ignition will be presented by A. H. Goldingham, De La Vergne Machine Co., who will treat of their application to stationary service for driving electric generators and other uses, while their use in marine service will be discussed by James Barnaby, Staten Island Shipbuilding Co. A paper dealing with the application of the Diesel type engine to stationary service will be presented by Max Rotter, Busch-Sulzer Bros. Diesel Engine Co., and T. O. Lisle, editor of *Motorship*, will discuss the adaptability of this engine to marine service.

At the meeting of the Mid-West Section held at Chicago on March 7, David Beecroft, managing editor of the Class Journal Publishing Co., delivered an address on conditions in the automotive industry abroad, based upon observations made during his recent trip to the war zone. He pointed out that while passenger cars were beginning to be built for the general market, the real post-war models would not appear for many months. The production of a $1,000 car by Renault indicated that European manufacturers were planning an invasion of a low-priced field, but he stated that the European manufacturer would not sacrifice the quality of his product for the quantity schedules that characterize the American output. In discussing the effect of the war on automobile design Mr. Beecroft said that European makers learned more from one Grand Prix road race than from the operation of airplanes throughout the entire war. This he attributed to the fact that the conditions under which aviation engines operate, particularly those that go up from 15,000 to 20,000 ft., are so different from those applying to automobile engines that there is practically no basis for making a comparison. The paper on the Possibilities of Steam Power which was presented by Prof. J. D. Nies at the meeting on Jan. 30 will be discussed at the next meeting of the Section, to be held April 11. Frank Jay and Mr. Dake, chief engineer of the Pyle-National Co., will also present papers.

At the meeting of the Minneapolis Section held March 5, F. N. G. Kranich, agricultural engineer, Hyatt Roller Bearing Co., presented a paper on Implements Designed for Tractor Belt Power and Their Characteristics. The other speaker at the meeting was J. B. Mooney, Auto Engine Works, St. Paul, Minn. His subject was Cylinder and Piston Refitting.

A very interesting meeting which was attended by about 250 members and guests was held at Buffalo on March 19. The speaker of the evening was G. Douglas Wardrop, managing editor of *Aerial Age Weekly*, who related a number of interesting facts concerning the part played by aircraft in the war. The talk was based almost entirely upon his experiences on the Western Front. The commercial use of aircrafts was also discussed.

In connection with the Aeronautic Meeting of the Society on March 7, the Metropolitan Section visited the plant of the Splitdorf Electrical Co., Newark, N. J. Members of the Society outside of the Metropolitan district attended as guests of the Section. An opportunity was afforded to inspect the plant before and after the luncheon which was served at the works. About 150 members and guests attended.

OBITUARIES

W. A. HAINES died at his home in Detroit, Mich., Feb. 11, from pneumonia following an illness of less than 24 hr. He was born at Minerva, Ohio, July 1, 1885, and was educated at the local high school, University of Wooster and Ohio State University. He entered the employ of the engineering department of the Westinghouse Electric & Mfg. Co. in 1907 and had charge of the stocking of all standard material and the economic manufacture thereof until June 1, 1913, when he was transferred to the sales department at Pittsburgh, Pa. He remained there until September, 1914, handling automotive starting, lighting and ignition apparatus. At that time he was transferred to the Detroit office and specialized in the same lines of equipment. In 1916, he was appointed assistant district manager of the Detroit office and in June, 1918, was made district manager. He is survived by his widow and a young son. Mr. Haines was elected to the Associate Member grade in the Society, Feb. 10, 1915.

OLIVER W. HALL died of Spanish influenza at Camp Raritan, Jan. 13. He was born at Sterling, Col., in 1892 and prepared for college in the high school there. His bent was mechanical and he began early to drive and repair automobiles. He went with the Ford Motor Co., Detroit, in 1911, and the following year took charge of its Fort Collins office. He had not completed his course in mechanical engineering at the University of Michigan when the call to war came. He volunteered in the Ordnance Department and was sent to the Raritan Training School where his work was instructing men in the driving and care of cars. He had been an Associate Member of the Society since 1913.

ELBERT L. SMITH died of bronchial pneumonia Jan. 29, 1919, while serving at a private in the 337th Infantry in France. He was born at Otsego, Mich., Dec. 16, 1894, and was graduated from Kalamazoo High School in June, 1915. From May to October, 1917, he was employed as a draftsman in experimental work on a piston-valve engine by the McIntyre Motor Co., Kalamazoo, Mich. From October, 1917, until he entered the service he was associated with the Barley Motor Car Co., also of Kalamazoo, as a draftsman, handling the engineering work of the company. Mr. Smith was elected to the Junior grade of membership in the Society, March 25, 1918.

WALTER H. STROM, president and treasurer of the U. S. Ball Bearing Mfg. Co., Chicago, Ill., died at his home in that city on Jan. 23. He was born in Chicago in 1890 and his education included a course in the high schools of that city and three years at the Lawrenceville Preparatory School. In 1912, he became general manager of the U. S. Ball Bearing Mfg. Co. and in addition served as secretary and treasurer. He was elected to Associate Member grade in the Society, Sept. 12, 1916. The cause of his death was Spanish influenza and his wife and child died from that cause in the same week.

PERSONAL NOTES OF THE MEMBERS

Ralph L. Adams has been discharged from the motor transport service, Quartermaster Corps, with the rank of first lieutenant, and is now connected with the engineering department at the Edward G. Budd Mfg. Co., Philadelphia. Prior to entering the Government service he was in the employ of this company as a designer.

Walter O. Adams has resigned as plant manager of the Erie Specialty Co., Erie, Pa., and has opened an office at 1038 Dime Bank Building, Detroit, Mich., as mechanical-chemical engineer, specializing in production and sales.

Edwin G. Anderson, who was formerly Pacific coast representative of the American Bronze Corporation, Berwyn, Pa., and later advertising and sales manager, has been elected secretary of the corporation.

Charles E. Barton is now associated with the engineering department of the Lincoln Motor Co., Detroit, Mich. He was formerly in the service of the Government, in the Bureau of Aircraft Production, and was stationed at McCook Field, Dayton, Ohio.

E. O. Bennett, formerly stationed at the research laboratory, National Advisory Committee for Aeronautics, Langley Field, Hampton, Va., is now associated with the engineering department of the Standard Oil Co., San Francisco, Cal.

F. H. Berger, chief engineer Grey Motor Co., Detroit, Mich., has opened an office as consulting engineer at 603 Hodges Building, that city. He still retains his connection with the Grey company.

Harold G. Bowker has resigned as chief draftsman of the Four Wheel Drive Auto Co., Clintonville, Wis., to accept a position as assistant chief engineer of the Topp-Stewart Tractor Co., of that city.

Lee C. Carlton has resigned as Chicago branch manager of the American Bosch Magneto Corporation, and has been appointed Mid-West manager of the Ericsson Mfg. Co., with offices in the Century Building, that city.

Ralph E. Cherry has severed his connection with the airplane experimental engineering division, Bureau of Aircraft Production, and is now chief engineer of the Stephen Motor Works of the Moline Plow Co., Freeport, Ill.

Ralph C. Chestnutt has resigned as layout draftsman with the Willys-Overland Co., Toledo, Ohio, and is now assistant chief engineer of the North American Motors Co., Pottstown, Pa.

W. C. Clancy, who was formerly connected with the aircraft division, Bureau of Construction and Repair, Navy Department, Washington, has severed his connection with the service.

A. L. Clayden has resigned as consulting engineer of the Wright-Martin Aircraft Corporation, New Brunswick, N. J., and will sail shortly for London, where he will open an office as consulting engineer. He plans to specialize in European investigations for American companies in the automotive field and will spend a portion of each year in this country.

Edwin M. Coe, who has been serving in France with mechanical repair shop unit No. 302, Quartermaster Corps, has been discharged with the rank of first lieutenant, and is now located at the Detroit branch of the Willard Storage Battery Co.

M. E. de Jarny, who was formerly in the service of the French Government, is now associated with the British Motor Cab Co., London.

Willis H. Diefendorf has been appointed general manager of the Weekes-Hoffman Co., Syracuse, N. Y. He was formerly chief engineer of the New Process Gear Corporation, also of that city.

Matthew C. Dittman, who had active charge of the affairs of the American Bronze Corporation, Berwyn, Pa., while its president, John W. Watson, was in Government service, has been reelected vice-president and treasurer and in addition appointed general manager.

Walter T. Fishleigh has severed his connection with the technical service branch, engineering division, Motor Transport Corps, and resumed his work as associate professor of automobile engineering at the University of Michigan, Ann Arbor.

Clarence M. Foss has been stationed at the Raritan Arsenal, Metuchen, N. J., as plans officer with the ordnance maintenance and repair schools located at this place for the last several months. He expects to remain there until certain details of the proposed ordnance training program are worked out. Capt. Foss received his commission with the Ordnance Reserve Corps, July 18, 1917, and was ordered into active service about one month later at the plant of the Nash Motors Co. In September of that year he was transferred to the Rock Island Arsenal and was placed in command of the engine instruction school there, a position which he held until June 1, 1918, when he was transferred to his present station.

Col. Edwin S. George has been relieved of his duties as chief of the motors branch, motors and vehicles division, Office of the Director of Purchase and Storage, War Department, and honorably discharged from the Army. After a vacation at Miami, Fla., he will return to Detroit about April 1, and resume his duties with the Packard Motor Car Co.

H. L. Greene has been appointed chief metallurgist of the Willys-Overland Co., Toledo, Ohio, and its allied companies. He was formerly chief metallurgist of the Canadian branch of the organization, the Willys-Overland, Ltd.

C. L. Halladay, formerly engineer in charge of the Washington office of the National Automobile Chamber of Commerce, Inc., has joined the organization of the Jackson Motor & Mfg. Co., Jackson, Mich.

S. E. Hanselman has resigned as production manager of the Youngstrom Auto Co., Des Moines, Iowa, and has been appointed superintendent of the Wood Bros. Tresher Co., of that city.

Curt E. Heckel has been discharged from the Motor Transport Corps with the rank of second lieutenant, and is now connected with the Pierce-Arrow Motor Car Co., Buffalo, N. Y.

Arthur H. Herts of the Automotive Products Corporation, New York City, has gone abroad in the interests of that organization.

F. Leroy Hill has severed his connection with the airplane engineering division, Bureau of Aircraft Production, and is now located at Berkeley, Cal.

John Hirtreiter has accepted the position of assistant engineer with the Beaver Mfg. Co., Milwaukee, Wis. He was formerly gasoline engine designer with the Holt Mfg. Co., Peoria, Ill.

Pliny E. Holt has severed his connection with the engineering division, Ordnance Department, and has resumed his former duties as the vice-president of the Holt Mfg. Co., Stockton, Cal.

Earl M. Hunker has resigned as assistant plant manager of the Cleveland Axle Mfg. Co., Canton, Ohio, and is now connected with the Cincinnati office of the Standard Parts Co.

Louis C. Jenkins has been appointed production manager for the Industrial Controller Co., Milwaukee, Wis.

Lewis P. Kalb has been appointed assistant to J. G. Utz, director of engineering, Standard Parts Co., Cleveland. He went to that organization from the engineering division, Motor Transport Corps, where he was in charge of design, testing and specification work with the rank of major. Prior to entering the Government service Mr. Kalb was chief engineer of the Kelly-Springfield Motor Truck Co., going to that organization from the Pierce-Arrow Motor Car Co., where he held the position of assistant truck engineer.

Other changes in the Standard Parts Co. include the reinstating of the plan of separate general management for the various plants which replaces the centralizing of all activities in the general offices during the war. Among the members of the Society who have been placed in charge of the different plants are H. H. Newsom, Standard Welding plant; George H. Kleinert, Bock Bearing plant; D. K. Moore, American Axle and Cincinnati Axle plants; J. B. Childe, Canton

Spring and Forge plants; B. A. Litchfield, Pontiac Spring plant, and N. B. Champ, St. Louis Spring plant.

Frank King has resigned as aircraft engineer, Wright-Martin Aircraft Corporation, New Brunswick, N. J., and is now associated with the Columbia Grafanola & Dictaphone Co., Fairfield, Conn.

Harry H. Levene has resigned as assistant chief engineer of General Motors Truck Co., Pontiac, Mich., and is now associated with the Monarch Governor Co., Detroit, Mich.

F. E. Ludolph, who was in the service of the Government as airplane mechanic, assigned to the Sixty-ninth Aero Squadron at Arlington Field, Houston, Tex., has been appointed chief engineer of the Harvey Motor Truck Co., Harvey, Ill.

Neil MacCoull is now associated with the Texas Co. as automotive engineer in the sales department, with headquarters at New York City, having returned from duty in France with the Naval Air Forces. Prior to entering Government service Mr. MacCoull was a mechanical engineer with the Westinghouse Electric & Mfg. Co.

Berne Nadall has resigned as sales engineer of the Stewart-Warner Speedometer Corporation after being connected with that organization for 7 yr. He intends to establish himself at Indianapolis as a representative of manufacturers of automobile parts and accessories.

O. M. Otte has resigned as construction engineer of the Interior Metal Mfg. Co., Jamestown, N. Y., and will devote his entire time to research work in the Newton Laboratories at that city, of which he has taken charge.

Glenn M. Ozias, who was formerly stationed at Post Field, Fort Sill, Okla., has been discharged from Government service and is now at Hazelton, Iowa. He has not made any plans for the future.

William F. Parish, manager of the lubrication division of the Texas Co. and lately chief of the oil and lubrication branch, Air Service, has been appointed technical director of the Sinclair Refining Co., Chicago, Ill.

W. E. Perrine is now associated with the Chevrolet Motor Co., New York City. He was formerly assistant general manager of the Standard Parts Co., Cleveland, Ohio.

Benjamin F. Pfeiffer is now in the tractor and ball-bearing section of the Chicago office of the New Departure Mfg. Co. He was recently discharged from the motor equipment section, engineering division, Ordnance Department, with the rank of first lieutenant. Prior to entering the service he was with the Diebold Safe & Lock Co., Canton, Ohio.

J. A. Polson has resigned as professor of mechanical engineering at the Michigan Agricultural College, East Lansing, Mich., to accept a position as factory manager with the Milwaukee Stamping Co., West Allis, Wis.

W. S. Quigley, president of the Quigley Furnace Specialties Co., New York City, recently sailed for Europe to spend several weeks in England, France and Italy to develop further the European connections of his company.

L. C. Reynolds has been appointed manager of the motor plant of the General Motors Corporation, located at Saginaw, Mich. He was formerly manager of the Detroit motor factory of the same organization.

F. E. Richardson has been transferred from Ann Arbor, Mich., to McCook Field, Dayton, Ohio, and assigned to the research department, airplane engineering division, Bureau of Aircraft Production.

G. M. Rymarczick has been appointed production engineer with the Simms Magneto Co., East Orange, N. J. He was until recently supervising senior inspector, magneto section, Bureau of Aircraft Production, and was stationed at New York City.

Henry Schaeffer has been appointed chief engineer of the Oneida Motor Truck Co., Green Bay, Wis. He was formerly assistant chief engineer of the Republic Motor Truck Co.

Louis J. Schneider, sales manager, Harrison Radiator Corporation, has been transferred from the Lockport, N. Y., plant to the office at Detroit, Mich.

Raymond L. Spragle has resigned from the Bureau of Aircraft Production and is now in the engineering department of the Aluminium Castings Co., Cleveland, Ohio. While in the Government service he was manager of the engineering records department with quarters at Detroit, Mich.

R. B. Stewart has resigned as production engineer of the Mobile Shipbuilding Co., Mobile, Ala., and is now in Chicago. He has not made any definite plans for the immediate future.

Percy F. Todd, who was connected with the engineering division, Bureau of Aircraft Production, at Detroit, Mich., is now with the tractor division of the General Motors Co., of that city.

Walter C. Voss, Washington sales representative of the Standard Parts Co., has been transferred to the axle division of the same organization at Cleveland, Ohio.

C. O. Walden, who has been in the Bureau of Standards as laboratory assistant in military gas engine research, is now associated with the Peru Auto Parts Co., Peru, Ind.

John W. Watson, who has been president of the American Bronze Corporation, Berwyn, Pa., since its foundation by him in 1906, has resigned. He is, however, retaining his holdings in the corporation and will continue to serve as a member of the board of directors. Some months ago he entered the Government service as director of publicity for the Philadelphia district, Ordnance Department, and later became assistant chief of the Hispano-Suiza engine section, Bureau of Aircraft Production.

Glenn S. Whithan, formerly service manager, Connell & McCone Co., Boston, Mass., has entered the employ of the Bethlehem Shipbuilding Corporation in the electrical department, and is located at Squantum, Mass.

CEMENTS FOR SPARK-PLUG ELECTRODES

CONSIDERABLE trouble has been caused in airplane engine work through the breaking of the central electrode of spark-plugs. An investigation of this problem was undertaken by the Bureau of Standards at the request of the Bureau of Aircraft Production. The results are given in Aeronautic Power Plants Report No. 35, which shows that in many cases the cement used to hold the nickel electrode wire in the porcelain is of such a nature that it rapidly eats away the wire through oxidization, when exposed to the high temperature of the engine cylinder. A cement composed of silicate of soda and raw kaolin has been found to give the least trouble in this respect.

In cases where the cement holds the wire firmly in the porcelain the latter often cracks when subjected to heat due to the difference in the coefficients of thermal expansion of the wire and the porcelain. The breaking of the porcelain does not seem to be due to leaky spark-plugs as has often been supposed to be the case.

On account of the difficulties attending the use of any form of cement between the porcelain and the central electrode, the elimination of the cement and the use of a mechanical seal at the top of the porcelain is greatly to be desired. In such a plug only a porcelain strong enough to withstand the resulting stresses safely should be used. The porcelain recently developed by the Bureau of Standards is believed to meet these requirements.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Feb. 15 and March 15, 1919. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (Aff. Rep.) Affiliate Representative; (S. E.) Student Enrollment

ARMSTRONG, RALPH W. (A) designer, Edward V. Hartford, Inc., 143 Morgan Street, *Jersey City, N. J.*

ATWELL, NORBERT S. (M) engineer, U. S. Ball Bearing Mfg. Co., 4535 Palmer Street, *Chicago, Ill.* (mail) 172 La Crosse Avenue.

BASQUIN, O. H. (M) engineer, Haskelite Mfg. Corporation, 821 Chamber of Commerce Building, *Chicago, Ill.*, professor of applied mechanics, College of Engineering, Northwestern University, Evanston, Ill. (mail) 821 Chamber of Commerce Building.

BECK, CHARLES W. (M) president, Michigan Motor Specialties Co., *Detroit, Mich.* (mail) 26 Dubois Street.

BECKER, SERGEANT DEWEY H. (J) draftsman, 811th Aero Squadron, Aviation Repair Depot, Speedway, *Indianapolis, Ind.*

BEIGER, JOHN W. (M) chief engineer and manager of factories, Haskelite Mfg. Corporation, Chamber of Commerce Building, Chicago, Ill. (mail) Haskelite Mfg. Corporation, *Grand Rapids, Mich.*

BERTRAND, A. A. (M) general superintendent, Chalkis Mfg. Co., 666 Mack Avenue, *Detroit, Mich.* (mail) 257 East Grand Boulevard.

BILL, HARRY L. (M) factory manager, Winton Co., *Cleveland, Ohio.*

BLODGETT, WALTER P. (M) manager of engineering, Standard Aircraft Corporation, Elizabeth, N. J. (mail) 204 West End Place, *Cranford, N. J.*

BOTZENHARDT, EUGENE W. (M) body draftsman, Dodge Brothers, *Detroit, Mich.* (mail) 662 St. Clair Avenue.

BRAENDER RUBBER & TIRE CO. (Aff. Mem.) *Rutherford, N. J.* Representatives:—F. L. Braender, president, W. P. Braender, secretary and treasurer, Frank B. Smith, chemist, J. E. Allen, sales manager.

BRANNAN, L. M. (M) chief engineer, Teetor-Hartley Motor Corporation, *Hagerstown, Ind.*

BUTTERFIELD, ROY O. (A) chief inspector, Velie Motors Corporation, *Moline, Ill.* (mail) 2416 Ninth Avenue.

CARPENTER, RALPH EMERSON (A) manager of laboratory and director of service, Aluminum Castings Co., *Cleveland, Ohio,* (mail) 2813 Coleridge Road.

CHAMINADE, LEON ABBETT (M) engineer, research laboratory, Studebaker Corporation, Brush and Piquette streets, *Detroit, Mich.* (mail) 29 Lothrop Street.

CHICAGO MALLEABLE CASTING CO. (Aff. Mem.) 12000 South Racine Avenue, *Chicago, Ill.* Representative:—J. S. Llewellyn, secretary.

CHRONIC, CLARENCE C. (M) designer, J. I. Case Threshing Machine Co., *Racine, Wis.* (mail) 1716 Holmes Avenue.

COCHRAN, BURL S. (M) production engineer, Grant-Lees Gear Co., 2365 East Sixty-ninth Street, *Cleveland, Ohio.*

COLE, CYRUS L. (M) sales engineer and sales manager, Wisconsin Motor Mfg. Co., Forty-fourth and Burnham streets, *Milwaukee, Wis.* (mail) 709 Fifty-first Street.

COLE, F. J. (M) chief consulting engineer, American Locomotive Co., *Schenectady, N. Y.* (mail) 3 Avon Road.

DAVIDSON, J. BROWNLEE (M) professor of agricultural engineering, University of California, Berkeley, Cal. (mail) University Farm, *Davis, Cal.*

DEAN, ERNEST W. (S. M.) petroleum chemist, U. S. Bureau of Mines, 4800 Forbes Street, *Pittsburgh, Pa.*

DE BELLEUSE, ALBERT C. (M) production expert, finance department, aviation section, Bureau of Aircraft Production, 360 Madison Avenue, *New York City.* (mail) Hotel Lafayette.

EDGERTON, C. W. (J) *Haverford, Pa.*

ENGLAND, WILLIAM ERNEST (M) designing engineer, Root & Van Dervoort Engineering Co., *East Moline, Ill.* (mail) 302 Sixteenth Avenue.

ERIE MALLEABLE IRON CO. (Aff. Mem.) *Erie, Pa.* Representatives:—G. R. Metcalf, president, E. E. Walker, vice-president, Andrew J. Sterrett, secretary, John R. Metcalf, treasurer, John W. Cox, engineer, W. Clay Missimer, assistant superintendent.

ERSKINE, JOHN STEVENS (M) chief draftsman, McCord Mfg. Co., 2587 East Grand Boulevard, *Detroit, Mich.*

EWING, JOSEPH (A) sales manager, Haskelite Mfg. Corporation, 120 Broadway, *New York City,* (mail) 103 East Eighty-sixth Street.

FELDINE, MICHEL (M) president, Lauraine Magneto Co., Inc., 1765 Broadway, *New York City.*

FISHER, A. W. (M) sales engineer, Hyatt Roller Bearing Co., Chicago, Ill. (mail) 74 New Montgomery Street, *San Francisco, Cal.*

FITZGERALD, WALTER L. (M) assistant works manager, Edward G. Budd Mfg. Co., Twenty-fifth Street and Hunting Park Avenue, *Philadelphia, Pa.* (mail) 231 East Durham Street.

FRANKEL, MORTIMER (M) assistant sales manager, Roller-Smith Co., 233 Broadway, New York City. (mail) Roller-Smith Co., 53 West Jackson Boulevard, *Chicago, Ill.*

FRAZER & JONES CO. (Aff. Mem.) *Syracuse, N. Y.* Representatives:—**Fred Frazer**, president, E. M. Griswold, secretary.

GORTZIG, HAROLD C. (J) inspection superintendent, tool and gage department, Curtiss Aeroplane & Motor Corporation, *Buffalo, N. Y.* (mail) 33 Wellington Road.

HARKNESS, JOHN L. (M) engineer of tests, L. W. F. Engineering Co., *College Point, N. Y.* (mail) 410 First Street.

HASTINGS, LIEUT. CLARENCE E. (J) inspector, Department of Militia and Defence, Canada. (mail) 252 Russell Hill Road, *Toronto, Canada.*

HAZARD, GEORGE E. (M) mechanical engineer, Kellogg Mfg. Co., 3 Circle Street, *Rochester, N. Y.*

HECKERT, FRED W. (M) production engineer, Green Engineering Co., 2 St. Clair Street, *Dayton, Ohio.* (mail) Young Men's Christian Association.

HERSEY, DWIGHT T. (A) assistant sales manager, Splitdorf Electrical Co., 98 Warren Street, Newark, N. J. (mail) 9 Inwood Place, *Maplewood, N. J.*

HIEGER, ROBERT H. (J) mechanical engineer, Byrne, Kingston & Co., *Kokomo, Ind.*

HUTCHINS, WILLIAM H. (M) engineering department, North East Electric Co., *Rochester, N. Y.* (mail) P. O. Box 1027.

IRELAND, W. S. (A) president, National Tool & Mfg. Co., 2536 University Street, *St. Louis, Mo.*

JACKSON, MELVIN F. (A) senior government inspector of aircraft and aircraft engines, Bureau of Aircraft Production, Wright-Martin Aircraft Corporation, *New Brunswick, N. J.* (mail) R. F. D. No. 6, Box No. 2, Hamilton Avenue.

JONES, H. D. (M) chief designer and mechanical engineer, Buffalo-Springfield Roller Co., *Springfield, Ohio.* (mail) 2806 East High Street.

KANE, JOHN V. (J) machine designer and draftsman, E. I. DuPont de Nemours & Co., Wilmington, Del. (mail) 1735 Mifflin Street, *Philadelphia, Pa.*

KLECKLER, HARRY (A) plant superintendent, Curtiss Aeroplane & Motor Corporation, *Hammondsport, N. Y.*

LACK, FRED S. (J) engineer, secretary and treasurer, Lack Mfg. Co., *Paducah, Ky.*

LASELLE, GEORGE W. (J) draftsman, Delta Electric Co., *Marion, Ind.* (mail) 523 West Sixth Street.

LEWIS, OTTO L. (M) chief engineer, tractor works, Moline Plow Co., *Rock Island, Ill.* (mail) 1157 Forty-fourth Street.

LINN, JOSEPH C. (M) works manager, Teetor-Hartley Motor Corporation, *Hagerstown, Ind.*

LITTLE, GUY A. (M) 103 University Street, *West Lafayette, Ind.*

LUDWIG, GEORGE R. (A) purchasing agent, raw material division, Curtiss Aeroplane & Motor Corporation, *Buffalo, N. Y.* (mail) 995 West Delaware Avenue.

LUM, PAUL B. (M) assistant manager, Autocar Sales & Service Co., 1240 Pennsylvania Avenue, N. W., *Washington.*

MCCANN, GEORGE BUELL (A) secretary and treasurer, Dayton Engineering Laboratories Co., *Dayton, Ohio.*

MARGOLIN, GEORGE (M) engineer, A. R. Mosler & Co., *Mt. Vernon, N. Y.* (mail) P. O. Box 292.

MARION MALLEABLE IRON WORKS (Aff. Mem.) *Marion, Ind.* Representative:—Edwin F. Leigh, vice-president and general manager.

MARTIN, LYLE B. (J) 97 Kenworth Road, *Columbus, Ohio.*

MAYO, EDWARD H. (M) consulting mechanical engineer, 1824 Broadway, *Indianapolis, Ind.*

MAYTHAM, EDWARD H. (M) assistant inspection engineer, Curtiss Aeroplane & Motor Corporation, *Buffalo, N. Y.* (mail) 545 Lafayette Avenue.

MEYER, WILLIAM H. (A) chief draftsman, National Tool & Mfg. Co., 2536 University Street, *St. Louis, Mo.* (mail) 3514 North Jefferson Avenue.

MITCHELL, F. ROBINS (A) president and treasurer, Mitchell & Smith, Inc., 1090 Commonwealth Avenue, *Boston, Mass.*

MIX, A. H. (A) construction and assembly foreman, airplane engine division, Bureau of Aircraft Production, McCook Field, *Dayton, Ohio,* (mail) 31½ Riverdale Street.

MORGAN, HARRY (M) chief mechanical engineer, Walker-Weiss Axle Co., *Flint, Mich.*

MORIARTY, SERGEANT GEORGE H. (A) office of chief of staff, motor and vehicle division, War Department, director of purchases and storage, *Washington,* (mail) 1413 T Street, N. W.

MOSES, EDMUND QUINCY (M) patent attorney expert, 52 Broadway, *New York City.*

MURPHY, PETER J. (A) general foreman, Steel Products Co., 514 Hart Avenue, *Detroit, Mich.* (mail) 1293 Crane Avenue.

NESS, NORMAN R. (J) draftsman, motor engineering department, Minneapolis Steel & Machinery Co., *Minneapolis, Minn.* (mail) 615 Hoag Avenue, North.

OLSON, ALLEN C. (A) mechanical draftsman, Standard Parts Co., Hicox Building, *Cleveland, Ohio,* (mail) 1336 East 114th Street.

PADGETT, JOSEPH EDWARD (J) assistant to research and experimental engineer, Nordyke & Marmon Co., *Indianapolis, Ind.* (mail) 6 West Michigan Street.

PARKER, CHARLES LESLIE (A) partner, Parker Motor Car Co., 1726 Broadway, *Seattle, Wash.* (mail) 921 Twelfth Avenue, North.

PRICE, J. P. (A) works manager, Curtiss Aeroplane & Motor Corporation, *Buffalo, N. Y.* (mail) 166 Summit Avenue.

RICHARDS, ARCHER W. (M) production manager, Standard Welding Plant, Standard Parts Co., Edgewater Park, *Cleveland, Ohio,* (mail) 10609 Clifton Boulevard.

RISBERG, M. M. (A) comptroller, Republic Motor Truck Co., Inc., Alma, Mich., M. & S. Corporation, Detroit, Mich., Torbensen Axle Co., Cleveland, Ohio, (mail) *Alma, Mich.*

ROSENTHAL, LEON W. (M) vice-president, American Bosch Magneto Corporation, Brightwood P. O., *Springfield, Mass.*

ROSS, ENSIGN EDWIN A. (M) inspector, bureau of construction and repair, U. S. Navy, Curtiss Aeroplane & Motor Corporation, *Buffalo, N. Y.* (mail) 23 Manchester Place.

SCHRODER, FRED (A) professional die casting engineer, 4534 North Sawyer Avenue, *Chicago, Ill.*

SCOFIELD, H. H. (M) assistant inspection engineer, Curtiss Aeroplane & Motor Corporation, *Buffalo, N. Y.* (mail) 262 Norwalk Avenue.

SHUTT, WALTER H. (M) director of all departments, H. J. Koehler Motors Corporation, 154 Ogden Street, Newark, N. J.; Associated Designers, 211 Summer Avenue, *Newark, N. J.* (mail) 211 Summer Avenue.

SIEBER, C. A. (A) mechanical draftsman, tank, tractor and trailer division, Ordnance Department, Sixth and B Streets, *Washington.* (mail) 3101 Thirteenth Street.

SJOGREN, OSCAR W. (M) professor of agricultural engineering, University of Nebraska, *Lincoln, Neb.* (mail) University Farm.
SMITH, CARLISLE F. (J) layout draftsman, Apperson Brothers Automobile Co., *Kokomo, Ind.* (mail) 814 West Mulberry Street.
SMITH, GEORGE MILTON (A) treasurer, Hill-Smith Metal Goods Co., 82 Brookline Avenue, *Boston, Mass.*
SMITH, HAROLD HOOPER (M) electrical engineer, Edison Storage Battery Co., Orange, N. J. (mail) 38 North Burnett Street, *East Orange, N. J.*
STEPHENSON, GEORGE F. (M) manager, E. P. Cooper Co., *Los Angeles, Cal.*, western representative and engineer, Wisconsin Motor Mfg. Co. (mail) 1310 South Los Angeles Street.
STOUT, WALTER D. (A) purchasing agent, Cole Motor Car Co., 742 East Washington Street, *Indianapolis, Ind.*
THORDEN, CARL (A) salesman, Curtiss Aeroplane & Motor Corporation, *Buffalo, N. Y.* (mail) 40 Lafayette Avenue.
TRASK, CLYDE W. (J) layout man, Chevrolet Motor Co., *Flint, Mich.* (mail) 1621 Bennett Avenue.
VOLLMER, WALTER G. (J) general manager and chief engineer, One Wheel Truck Co., 2122 Chouteau Avenue, *St. Louis, Mo.*
WALLACE, DAVID A. (M) mechanical engineer, Waterloo Gas Engine Co., *Waterloo, Iowa.*

Applicants *for* Membership

The applications for membership received between Feb. 20 and March 29, 1919, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ABEL, GEORGE K., draftsman, Militor Corporation, *Jersey City, N. J.*
AUMENT, CARROLL M., consulting engineer, Aument & Gillespie, 87 Nassau Street, *New York City.*
BAKER, E. J., JR., associate editor, *Farm Implement News, Chicago, Ill.*
BARNES, ROSS J., engineering department, Service Motor Truck Co., *Wabash, Ind.*
BARRESS, J. E., associate mechanical engineer, Timken Roller Bearing Co., *Canton, Ohio.*
BARRY, WILLIAM C., vice-president and general manager, Selden Motor Vehicle Co., *Rochester, N. Y.*
BISP, WILLIAM E., draftsman, Militor Corporation, *Jersey City, N. J.*
BRAY, JAMES S., chief draftsman, Allison Experimental Co., *Indianapolis, Ind.*
BIRD, ROBERT M., metallurgist, Bethlehem Steel Co., *Bethlehem, Pa.*
CAIN, THOMAS A., general manager, Reo Motor Sales Co., *Toronto, Canada.*
CARY, EMMETT F., master electrician, headquarters detachment, Air Service, *St. Paul, Minn.*
CATHCART, CHESTER A., production executive, Dayton Wright Airplane Co., *Dayton, Ohio.*
CLARK, EUGENE B., president, Clark Equipment Co., *Buchanan, Mich.*
COOK, JOHN, chief engineer, Elkhart Carriage & Motor Car Co., *Cleveland, Ohio.*
CUNNINGHAM, ROY H., aeronautical designer, Curtiss Engineering Corporation, *Garden City, N. Y.*
DEARBORN, FOREST E., service engineer, Waltham Watch Co., *Waltham, Mass.*
DRIGGS, IVAN H., mechanical engineer, experimental division, Bureau of Aircraft Production, McCook Field, *Dayton, Ohio.*
DU PONT, FRANCIS V., mechanical engineer, E. I. du Pont, de Nemours & Co., *Wilmington, Del.*
EADE, WALTER F., aeronautical engineer, research department, airplane engineering division, Bureau of Military Aeronautics, McCook Field, *Dayton, Ohio.*
EDWARDS, EATON G., field sales, field engineering and test work, G & O Mfg. Co., *New Haven, Conn.*
FARNSWORTH, FRANK B., vice-president, Palmer Brothers Co., *Chicago, Ill.*
FOSTER, FRANK M., distributor of motor trucks, 980 Jefferson Avenue, East, *Detroit, Mich.*
GOLDMAN, FIRST-LIEUT. J. M., general staff, Quartermaster Corps, *Washington.*
GRACEY, ROBERT G., engine designer, Minneapolis Steel & Machinery Co., *Minneapolis, Minn.*
HAAS, JOSEPH F., vice-president and service manager, Couch, Haas Company, Inc., *Brooklyn, N. Y.*
HARRIS, HIRAM F., sales manager and industrial engineer, Republic Motor Truck Co., Inc., *Alma, Mich.*
HEMINWAY, M. L., general manager, Motor and Accessory Manufacturers Association, *New York City.*
HEWITT, CECIL M., chief instructor, Bradley Polytechnic Institute, *Peoria, Ill.*
HEWITT, WALTER F., foreign sales engineer, Four Wheel Drive Auto Co., *Clintonville, Wis.*
HILL, G. CLIFFORD, superintendent, Eldridge Buick Co., *Seattle, Wash.*
HOLMES, CHARLES D., chief engineer, C. B. Cottrell & Sons Co., *Westerly, R. I.*
HOUSE, ELLIS H., in charge of planning department, Holt Mfg. Co., *Stockton, Cal.*
HOWARD, LESLIE E., metallurgist, Simonds Mfg. Co., *Lockport, N. Y.*
HOWE, RALPH S., superintendent of production, Standard Aircraft Corporation, *Elizabeth, N. J.*
HOWELL, J. BERTRAM, sales engineer, Bound Brook Oil-less Bearing Co., *Bound Brook, N. J.*
IRVINE, JAMES R., layout draftsman, Holt Mfg. Co., *Stockton, Cal.*
JAGGERS, GEORGE WASHINGTON, acting chief draftsman, Mercer Automobile Co., *Trenton, N. J.*
JOHNSON, FRED J., mechanical draftsman, Gray Tractor Co., Inc., *Minneapolis, Minn.*
JOSEPHS, LYMAN C., JR., engineer, International Motor Co., *New York City.*
KAUKE, JOHN H., inspector of airplanes and airplane engines, Bureau of Aircraft Production, *New York City.*
KEIHN, CHARLES A., assistant inspector of engineering and aeronautic material, U. S. Navy, 411 Fifth Avenue, *New York City.*
KEIHN, FERD. A., designer, W. E. Kemp, 1733 Broadway, *New York City.*
KEPKE, JOHN, JR., salesman, S. K. F. Ball Bearing Co., *Hartford, Conn.*
KERN, WALTER C., secretary and production manager, W. G. Hesse & Son Mfg. Co., *Leavenworth, Kan.*
LAWRENCE, GUY E., checker, Bureau of Aircraft Production, McCook Field, *Dayton, Ohio.*
LANDAU, HENRY B., general foreman of assembling and tests, Wright-Martin Aircraft Corporation, *New Brunswick, N. J.*
MAHONEY, JOSEPH N., consulting engineer, Sperry Gyroscope Co., *Brooklyn, N. Y.*
MELTON, LLOYD L., vice-president and chief engineer, Haury Motor Co., *Chicago, Ill.*
MICHIE, EDWIN R., vice-president, Ordnance Engineering Corporation, *New York City.*
MILSTREY, SECOND-LIEUT. HENRY F., officer in charge of air service automotive school, General Hospital No. 11, *Cape May, N. J.*
NEWCOMB, BENJ. R., patent section, administration division, Ordnance Department, *Washington.*
OETZEL, J. GEORGE, assistant to works engineer, General Electric Co., *Erie, Pa.*
OLIVIERE, H., machinist, American Bolt Co., *Birmingham, Ala.*
PIEL, CARL W., secretary, Pioneer Brass Works, *Indianapolis, Ind.*
QUAM, JAMES P., chief engineer, United Mfg. & Distributing Co., *Chicago, Ill.*
RAY, WARWICK, sales department engineer, Stewart-Warner Speedometer Corporation, *Detroit, Mich.*
REAGAN, FIRST-LIEUT. CHARLES A., Chicago district, Ordnance Department, *Chicago, Ill.*
RECKFORD, JOHN K., assistant secretary, American Lead Pencil Co., *New York City.*
REDDAN, JOHN A., draftsman, National Tool & Mfg. Co., *St. Louis, Mo.*
REED, LEON H., designer, Standard Parts Co., *Cleveland, Ohio.*
REID, ROBERT H., treasurer, Master Trucks, Inc., *Chicago, Ill.*
ROYCE, ALFRED C., engineer of tests, Ordnance Department, Standard Steel Works, Co., *Burnham, Pa.*
ROSSITER, WYNN F., metallurgist, McKinnon Industries, Ltd., *St. Catherines, Ontario, Canada.*
SANDIESON, PATRICK, chief engineer and production engineer, Pittsburgh Model Engine Co., *Pittsburgh, Pa.*
SEAHOLM, ERNEST W., engineer, Cadillac Motor Car Co., *Detroit, Mich.*
SHOEMAKER, JOHN H., service manager, Ericsson Mfg. Co., *Buffalo, N. Y.*
SMITH, BRENTON A., checker, airplane engineering division, Bureau of Aircraft Production, McCook Field, *Dayton, Ohio.*
SPENCE, DAVID, vice-president and general superintendent, Norwalk Tire & Rubber Co., *Norwalk, Conn.*
STRAUB, JOSEPH C. A., experimental engineer, Hall Scott Motor Car Co., *Berkeley, Cal.*
STORM, A. J., sales representative, Dayton Steel Foundry Co., *Dayton, Ohio.*
SWIFT, FRED. H., service manager, Franklin Motor Car Co., *Utica, N. Y.*
SWIFT, WILLIAM K., sales engineer, Bound Brook Oil-less Bearing Co., *Bound Brook, N. J.*
TAYLOR, B. G., engineer, Department Public Works, *New South Wales.*
TWITCHELL, STANLEY A., instructor of gas engine and automobile classes, public schools and Central High School, *Minneapolis, Minn.*
WALSH, W. F., owner, Walsh & Johnson, *Tulsa, Okla.*
WARD, OLIVER, aeronautical draftsman and checker, Curtiss Engineering Corporation, *Garden City, N. Y.*
WEBB, A. B., chief engineer, Monarch Tractor Co., *Watertown, Wis.*
WILSON, CYRIL, layout draftsman, National Motor Car & Vehicle Corporation, *Indianapolis, Ind.*
WOODSIDE, WILLIAM P., consulting metallurgist, Studebaker Corporation, *Detroit, Mich.*
WHITTET, A. B., draftsman, artillery division, Ordnance Department, Holt Mfg. Co., *Stockton, Cal.*
YOCUM, ALVIN M., chief draftsman, North American Motors Co., *Pottstown, Pa.*
YOUNG, FRED. M., sales engineer, Perfex Radiator Co., *Racine, Wis.*
ZELLE, WILLIAM C., president, Zelle Tractor Co., *St. Louis, Mo.*